

**DEVELOPMENT OF A TEST FOR SCIENTIFIC LITERACY AND ITS  
APPLICATION IN ASSESSING THE SCIENTIFIC LITERACY OF  
MATRICULANTS ENTERING UNIVERSITIES AND TECHNIKONS IN THE  
WESTERN CAPE, SOUTH AFRICA**

by

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## ABSTRACT

This exploratory study was conducted against the background of immediate post-apartheid South Africa in which the social upliftment and improvement of living conditions of all South Africans is regarded as of the highest priority. In a science- and technology-orientated world, science and technology is inextricably linked to this process. The purposes of this study were (a) to determine the level of scientific literacy of matriculants entering tertiary education in the Western Cape for the first time; (b) to describe patterns of scientific literacy levels with respect to selected demographic and other student background variables; and (c) to ascertain which student background variables appear to have the most influence in determining whether matriculants are scientifically literate or not. A survey was deemed to be appropriate for answering the above research questions. Underpinning the study was the development of a pool of scientific literacy test-items, from which a criterion-referenced, reliable, valid, and composite scientific literacy test instrument - the *Test of Basic Scientific Literacy* - could be constructed.

The development of a pool of 472 paper-and-pencil test-items of scientific literacy was based on selected chapters of the 1989 American Association for the Advancement of Science (AAAS) overview report on literacy goals in science, mathematics and technology, entitled *Project 2061 - Science for All Americans*. Separate pools of test-items were developed for each of Miller's (1983) "three constitutive dimensions" of scientific literacy, namely the nature of science, science content knowledge, and the impact of science and technology on society. To ensure as broad a content coverage as possible, a "True-False-Don't Know" item format was chosen. Test-items were generated using Roid and Haladyna's (1982) sentence transformation item-writing method. Forty-one randomly chosen Fellows of the Royal Society of South Africa in appropriate scientific disciplines validated subjectively-chosen key sentences containing important ideas in, and attitudes toward, science. A summary of 240 key sentences was compiled, and sentences were transformed into matched True-False test-items. Content validity was assessed separately, and the item representativeness and the technical quality of items were evaluated by 21 South African university lecturers. The language demand of items was assessed and modified by an experienced linguist and an English Second Language expert. The test-items were shown to possess high content and item validity, and can be used for constructing measures of scientific literacy, or any of its dimensions, directed at a number of different target groups for a variety of purposes in South Africa or elsewhere.

Test-items were pilot-tested on 625 technikon and university students. On the basis of item discrimination, item difficulty and student feedback, 110 test-items were selected to form the *Test of Basic Scientific Literacy* (TBSL). The TBSL consists of three subtests, each corresponding to one of Miller's three constitutive dimensions of scientific literacy. About 260 national members of various South African professional science and engineering associations participated in setting a performance

standard for each of the subtests. These standards were validated using a “contrasting groups” approach using 138 national science olympiad winners and 74 local college of education students. The internal consistency of the individual TBSL subtests, and the reliability of mastery-nonmastery classification decisions based on the performance standards, was found to be about 0.80. The reliability of the overall 110-item TBSL was 0.95. The TBSL is unique in that compared to other currently available composite measures of scientific literacy it is unmatched in the degree of confidence that the test-items used in such instruments correspond to the major content areas of the theoretical concept the tests are designed to measure.

The scientific literacy survey questionnaire consisted of the TBSL and a further section which sought to obtain self-reported retrospective data on student background variables in a number of different areas: demographic, educational, and socio-economic. These socio-demographic variables were largely - but not exclusively - based on and coded similarly to appropriate ones used in the 1987 Longitudinal Study of American Youth. Overall, 53 variables and unobserved variables (i.e., latent constructs) were available for investigating the scientific literacy of matriculants. At the beginning of the 1994 academic year, the scientific literacy survey questionnaire was administered to 6801 first-year students registered in a variety of different academic disciplines at the Universities of Cape Town, Stellenbosch, and the Western Cape, as well as at the Cape and Peninsula Technikons. The final sample, on which the findings described below were based, consisted of 4227 first-time entering students.

Students were classified as scientifically literate or illiterate on the basis of their performance on the TBSL. The level (i.e., proportion) of scientific literacy of students from different population groups was found to vary greatly, and a clear hierarchy was evident with respect to all variables examined. “White” and “Indian” students were most scientifically literate, followed by “Coloured” and thereafter by African students. This hierarchy was shown to be related to the hierarchy of inequality evident with respect to the school and home environment of students from different population groups. Overall, male students displayed statistically significantly higher levels of scientific literacy than female students, as did university compared to technikon students. In general, students registered for degrees or diplomas in Engineering had the highest level of scientific literacy, followed by students in the Natural Sciences. Next were students in Commerce and Management, while students in the Human Sciences had the lowest level of scientific literacy. Engineering students were found to have a statistically significantly higher proportion of parents with a science-related occupation than other students, and were also found to have parents who were more likely to exercise a ‘science push’ than parents of non-engineering students. In general, levels of scientific literacy decreased with increasing age of students. In this study the overall scientific literacy levels with respect to major school-related variables followed anticipated patterns. Different science subjects, and different combinations thereof, influenced the level of scientific literacy of students from all population groups. The level of scientific literacy of students who included Physical Science in their science subject combination was consistently higher than that of students who did not,

and it was shown that students taking only Physical Science possessed a better understanding and awareness of all three dimensions of scientific literacy - based on TBSL subtest scores - than students taking only Biology. The effect of taking Geography in senior years of high school was found to be similar, and not additive, to that of taking Biology, suggesting that there is no obvious advantage to taking Geography in addition to Biology in terms of increasing students' level of scientific literacy.

Just over one third of matriculants entering universities and technikons in the Western Cape can - on the basis of the TBSL - be regarded as scientifically literate. Based on the overall level of scientific literacy of students from different population groups, and given a number of assumptions, it is speculated that the science education provided by the recent South African education system to "White" students may be regarded as reasonably acceptable, whereas that available to African and "Coloured" matriculants does not reach even minimally acceptable levels. The very low number of "Indian" students precluded an opinion being formed on the science education available to this group of students.

Logistic regression was used to identify current predictors of the scientific literacy of matriculants in order to reveal those factors that appear to have the most influence on whether matriculants are scientifically literate or not. The data structure suggested a separate logistic regression model for "White" and "Indian" students, and for "Coloured" and African students. The models revealed that all groups of South African matriculants - based on the present student sample - share a set of student background variables that are associated with scientific literacy, namely science subject combination, interest in science, and academic home resources that were believed to point towards a generally supportive and educationally conducive home environment. Science club membership was found to be associated only with the scientific literacy of "White" and "Indian" students, whereas overall matric result and motivation were found to be associated only with the scientific literacy of "Coloured" and African students.

Based on the findings of this study, a number of recommendations are made with respect to improving the general level of scientific literacy of South African matriculants. The findings have also generated a number of hypotheses and research questions which provide important directions for further research in both the South African, as well as in a general, context related to scientific literacy and science education. Carried out in the immediate post-apartheid era, the study provides unique baseline-data which may be used to assess the impact on scientific literacy of improved provision of education and the changed socio-economic priorities currently being implemented in South Africa.



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## Chapter One

### GENERAL INTRODUCTION

The period surrounding the peaceful transition of political power in South Africa has provided a unique window of opportunity to consider, debate, and deliberate on South Africa's future and the shape it should take. Consequently it is now widely acknowledged that the social and economic inequities existing in the country as a result of previous apartheid policies need to be urgently addressed through redress and development, both in terms of human resources and economic progress. It is generally accepted that science and technology play a major role in the economic development of a country (e.g., Bloch, 1986; Lewis, 1982). The establishment of an appropriate science education policy that is logically consistent with the national policy for science and technology is acknowledged to be important both to this overall development process as well as to the more goal-directed development of human resources in South Africa (e.g., Amuah, 1994ab; Branscomb, 1994; Department of Arts, Culture, Science and Technology [DACST], 1996; Ellis, 1993, 1994; Lewin, 1992, 1995; National Education Policy Investigation [NEPI], 1993; Ogunniyi, 1996).

Scientific literacy - which "commonly implies an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas" (Jenkins, 1994, p. 5345) - is now widely considered to be a major goal of science education throughout the world, and a scientifically literate citizenry is regarded as essential for economic prosperity and social progress in South Africa (Kahn & Rollnick, 1993; Pouris, 1989, 1992; Schreuder, 1994; Spargo, 1995a). It is in this context that this exploratory study investigates the level of scientific literacy of successful high-school leavers (i.e., matriculants) at the secondary/tertiary education interface in South Africa. The study is based on a large-scale survey of first-time entering students at the five major tertiary educational institutions in the Western Cape - one of the nine newly defined provinces of South Africa - and describes patterns and predictors of scientific literacy amongst this group of matriculants. Underpinning this survey is the construction of a reliable, valid, and rigorous *Test of Basic Scientific Literacy* which - in the context of Miller's (1983) 'three constitutive dimensions' definition of scientific literacy - was based on selected scientific literacy goals recommended by the American Association for the Advancement of Science (AAAS) in their publication *Project 2061 - Science for all Americans* (AAAS, 1989). In general, an essentially complementary approach to the current research framework widely used in national and cross-national surveys of scientific literacy (e.g., Miller, 1992) was employed.

This chapter provides a general outline of the reasons as to why scientific literacy is believed to be important for South Africa, and provides a brief overview of education in this country in order to place

the decisions taken during this research in the appropriate historical and political context. The study is delineated thereafter, a literature review of research in scientific literacy conducted in South Africa to date provided, and an outline given of dissenting opinions with respect to the concept of scientific literacy.

## SCIENTIFIC LITERACY FOR SOUTH AFRICA

The general election in South Africa in April 1994 has without question resulted in a great sense of freedom, relief, and joy for the overwhelming majority of the population. However, the new-found freedom from the political, economic, and emotional shackles linked to apartheid may prove to be a limited - if not hollow - victory without some discernible concomitant improvement in the quality of life for millions of disadvantaged South Africans. In this regard, South Africa is facing a number of serious challenges which include *inter alia* a rapidly growing population (the 1995 estimated rate of increase for the population of 40.6 million is 2.3%), increasing urbanisation (with its associated problems of overcrowding, health, etc.), and a high unemployment rate that currently stands at 32.6% for the overall population but is particularly alarming for Africans<sup>1</sup> (Table 1.1) (Central Statistical Services [CSS], 1995; Spargo, 1995a).

If the availability of rudimentary services such as, for example, running water, electricity, and sanitation - which are regarded as the norm in industrialised countries - is taken as a rough indicator of the quality of life of most South Africans, the picture is indeed gloomy. Relevant data from the 1994 October Household Survey (CSS, 1995) show large discrepancies between South African households (Table 1.1). Only an estimated 27.4% of African households have running tapwater inside their homes, whereas the corresponding figure for Whites is 98.4%. Most Coloured, Indian, and White households use electricity from a public supply as the main energy source for cooking, while only 30.5% of African households do so. As far as sanitation is concerned, an estimated 12.6% of African households have no facilities in this regard (CSS, 1995). Whereas between 80% and almost 100% of Coloured, Indian, and White households have a flush toilet, only 34.1% of African households do (Table 1.1). More than 75% of Whites have access to a medical aid benefit fund (i.e., health insurance), as compared to only 9.2% of Africans.

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1. Population group categories used here, that is African, Coloured, Indian, and White, follow former South African legislative practise. The categories are used to highlight differences due to the education previously available to "racial" groups created by apartheid policies, and their use does not intend to imply legitimacy to these categories.

**Table 1.1.** The South African population size, unemployment rate, and availability of services in African, Coloured, Indian, and White households (as a percentage of homes) according to the 1994 October Household Survey (CSS, 1995).

	African	Coloured	Indian	White	Overall
Population figure (million)	30.94	3.47	1.04	5.19	40.64
Unemployment rate (%)	41.1	23.3	17.1	6.4	32.6
Running tapwater inside home (%)	27.4	76.0	97.7	98.4	47.6
Electricity from a public supply source as main energy source for cooking (%)	30.5	75.5	98.5	98.2	49.7
Flush toilet (%)	34.1	83.3	97.1	99.9	53.1
Access to medical aid benefit fund (%)	9.2	24.1	28.4	76.4	32.7

It is therefore clear that enormous headway needs to be made in order to achieve the urgent social upliftment of many South Africans. The magnitude of this task makes it obvious that this socio-economic development is a long-term activity that will require very substantial financial and human resources. It is now widely recognised that the economic success and vitality of any nation is linked to science and technology (e.g., Bloch 1986; Lewis, 1982), and the strong, sustained, long-term economic growth that South Africa requires in order to address meaningfully the many socio-economic challenges it faces must to a large extent depend on the quantity and 'quality' of the country's human resources (see, for example, Landau, 1988).

Scientifically literate high-school leavers would thus appear to be a *sine qua non* for economic and human resource development for at least three, not necessarily mutually exclusive, reasons. Firstly, to provide the large manpower pool in science, engineering, and technology that is needed to achieve appropriate economic growth. Secondly, in order to provide an increased likelihood of sound decision-making (a) in the application of science and technology in addressing some developmental issues (e.g., the provision of alternative energy, sanitation, etc.); (b) in the face of some large pressures that will unquestioningly be placed on the environment in view of the industrialisation and urbanisation that must accompany social upliftment in South Africa, and the high population growth (see, for example, Howell [1992] for a discussion of scientific literacy as the missing prerequisite for sound decision-making with respect to environmental policy in the United States); and (c) in their personal lives with respect to science-related issues (e.g., health, nutrition, etc.). Thirdly, as a means of empowering individuals to participate meaningfully in the democratic practices of a society with a growing science and technology base (Prewitt, 1983).

## Economic argument

It has been argued that the current economic crisis in South Africa can be attributed to the fact that South Africa does not have, in world terms, a well-established industrial or manufacturing sector, and that previous industrialisation has been largely based on import substitution (Gelb, 1991). It has therefore been suggested that South Africa needs to move away from the export of mainly primary products such as minerals and agricultural products, in order to achieve the economic success required for broad social upliftment (Gelb, 1991; NEPI, 1993; Pouris, 1989). The price of general primary commodities relative to that of manufactured goods has been shown to have declined by about 0.5% per annum for the period 1900-1986 (Grilli & Yang, 1988; cited by Pouris, 1989), and it has been proposed that South Africa should increasingly focus on beneficiation: adding value to primary products by processing them locally, before trading these manufactured goods on world markets for greater profits (AS&TS, JCSS, & SAVI, 1993; Freund, 1992; Gelb, 1991; NEPI, 1993; Pouris, 1989). Beneficiation, however, requires a pool of qualified manpower in science, engineering, and technology not only in order to identify and exploit niches in world markets, but also to select, design, plan, and oversee the manufacturing processes that are increasingly edging closer to state-of-the-art science and technology.

Closely linked to the above argument is the competitiveness of the science and engineering workforce in any nation, and the changing paradigm of how production processes are organised in the global context. It has been argued that the developing countries likely to grow fastest are those that adopt new methods of production such as, for example, elements of the post-Fordist production technologies (Kaplinsky & Posthuma, 1994; cited in Lewin, 1995). (The following brief description of relevant Fordist and post-Fordist production features is based largely on Lewin [1995] but also on Kraak [1991].) Fordist types of production (named after the automobile assembly lines first built by Henry Ford in 1914) depend on maximising machine utilisation and minimising labour costs, that is production is 'pushed' through by the need of each part of the factory to keep producing. This process is based on a 'just in case' mentality with respect to materials needed for production, so that materials are accumulated in stores and always available. Labour is necessary only at the lowest level compatible with full utilisation of machines, and quality control is appended to the production process and carried out by a special group of workers. Thus a "hierarchical division of labour with jobs that are narrowly defined and single task orientated" (i.e., Taylorism) is associated with this method of production (Kraak, 1991, p. 41).

Post-Fordist production technologies, on the other hand, regard machine utilisation rates as subordinate to the need for production to be 'pulled' through by orders, this process being characterised by a 'just in time' mentality in which material inventories are minimised. For the purpose of the argument developed here, one of the characteristic features of post-Fordist production technologies is the extent to

which labour is regarded as an asset to be flexibly used to improve the quality and efficiency of the production process, that is, quality control is integrated into the production process rather than appended. In addition, the change from Fordist to post-Fordist production techniques results in a shift of emphasis from 'economics of scale' to 'economics of scope' in which the production of a variety of products has become important. In the post-Fordism paradigm labour is therefore used to achieve both product quality and product variation, and workers have become a key source of innovation (Kraak, 1991). This changed role of labour implies that the workforce will need to have some understanding of the principles of the science and technology being applied in the various production processes, and will need to be skilled in elementary statistics as well as in the various co-operative styles of problem diagnosis and decision-making employed by such continuous improvement production processes (Lewin, 1995). It is thus the greater contribution of an educated workforce that is essential to the success of post-Fordist production technologies, and it is clear that a sizeable workforce with at least some basic grounding in science, engineering, and/or technology will be required for such methods of production to be successful.

Unfortunately, South Africa's manpower pool does not compare favourably with other countries in terms of the relative size of its science and engineering workforce (Foundation for Research Development [FRD], 1993). For example, while Australia can hardly be described as an advanced industrial country compared to Japan or Germany, Australia in 1989 nevertheless produced around six times more engineers (per 100 000 population) than South Africa (van Vuuren & Pouris, 1992). Moreover, with a ratio of 0.8:1, South Africa appears to have a particularly low ratio of technicians to scientists and engineers (Pouris, 1989). It is therefore alarming that the trend of enrolments in science and engineering related fields of study at universities and technikons<sup>2</sup> - the major tertiary educational institutions in the country - has not grown significantly in recent years. Whereas from 1985 to 1991 enrolment in university degrees in the social sciences and humanities experienced an average annual growth of 7%, the corresponding increase of enrolment in the natural sciences and engineering was only about 2% (FRD, 1993). The situation is even worse at technikons, where a significant move away from enrolments in science and engineering towards commerce and management diplomas has been identified for the comparatively short period between 1988 and 1991 (Cooper, 1995). To compound matters, Pouris (1991a) found in an analysis of the production of graduates at 12 South African universities for the period 1984-1988, that no South African universities could be regarded as 'technological' (i.e., a science to arts graduate ratio of 2:1) or even as 'general' (i.e., a ratio of 1:1): all universities produced more arts than science and engineering students. South Africa's current ability to produce the labour force skilled

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2. South African technikons are tertiary educational institutions where the emphasis in teaching and research is placed more on the practical, rather than the theoretical, aspects of a variety of disciplines. Technikons are now widely regarded as equivalent in status to a university. (For a description of the history and role of technikons in South Africa the reader is referred to Pittendrigh [1988].)



in science, engineering, and technology thought necessary in order to achieve the economic success urgently required for social upliftment is therefore seriously in doubt.

The relationship between scientifically literate high-school leavers and increased enrolments in science and engineering degrees or diplomas at tertiary institutions is clearly not a simple one. Other factors come into play and include the existence of a national policy and strategy for science and technology, funding policies of the national government with respect to science and technology and tertiary education, admission policies of tertiary institutions, the existence of enrolment incentives such as scholarship and bursary schemes, the perceived importance of science and technology in providing opportunities to gain a well-paid job, perceived prestige of science- and engineering-related careers, and so forth. Nevertheless, it is not unreasonable to assume that if high-school leavers are scientifically literate, i.e. students have some scientific understanding of the world around them and have some awareness of the extent to which science and technology interact with and impact on society, there will be an increased likelihood that many more high-school leavers will opt for further studies in science and engineering, and thus substantially increase the science and engineering workforce.

### **Decision-making argument**

The second major reason for promoting scientific literacy in South Africa addresses decision-making processes at the collective (i.e., national) and individual level. Turning to the collective level first, it must be recognised that science and technology not only play an important role in the envisaged process of vigorous national economic growth, but also in the solution of some challenges related to development. The sighting of new manufacturing industries and the provision of, for example, water, sanitation, energy, housing, transport, and telecommunications will in all likelihood increasingly require citizens to make decisions about socio-scientific issues. In addition, rapid human population growth has been rated both by professional ecologists and business leaders as the most serious environmental issue facing South Africa (Preston, Fuggle, & Siegfried, 1989). From this issue spring a number of other important concerns such as, for example, water availability, soil erosion, and desertification (Preston et al., 1989). Just keeping up with the current population increase in terms of housing, job creation, and the provision of general infrastructure such as roads and transport will inevitably place strains on the environment; addressing the tremendous backlog that exists in such areas for many Black<sup>3</sup> South Africans (see, for example, Table 1.1) will undoubtedly heavily compound such strains. Ill considered, rapid development of the population could clearly have irreversible, negative environmental consequences for South Africa. It therefore seems vital that a sizeable proportion of South Africa's future business, community, and political leaders (i.e., today's matriculants) should be able to view the developmental and environmental

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3. The term 'Black' refers to persons previously classified as African, Coloured, or Indian.

issues facing South Africa - and the use and application of science and technology in addressing these issues - in overall perspective. This, in turn, will hopefully promote a more informed decision-making process, and hence may result in more appropriate - and hence hopefully better - decisions being made in areas where science, technology, and society interface.

The argument for promoting scientific literacy for the benefit of decision-making at the individual level follows along similar lines to the reasoning above. Scientifically literate South Africans will have a working understanding of some of the scientific phenomena in the world around them (e.g., lightning, echoes, eclipses, etc.), and are therefore likely to find everyday life to be less terrifying and mystifying; they are thus more able to take charge of their life (Spargo, 1995b). Such individuals will lessen the likelihood of becoming, as Wharton (1981; quoted in Prewitt, 1983, p. 53) has put it so aptly, “ ‘techno-peasants’: modern-day serfs, nominally free but disenfranchised by ignorance - and fear - of prevailing technologies’ ”. Thus, by the application of simple scientific principles to everyday issues such as, for example, nutrition, health, and safety, scientifically literate individuals are also likely to be able to improve the quality of their own life (Spargo, 1995b).

The sensitisation of individuals to national or regional issues related to science and technology, as well as the empowerment of individuals with respect to their own lives, is related to the role such scientifically literate individuals are believed to be able to play in society in general. This argument is described next.

### **Democratic argument**

The democratic argument for the need of scientifically literate individuals in South Africa arises from the social application of skills described in the above sections. In a science- and technology-orientated society, many decisions need to be taken that involve the role of science and technology in public policy. Unless citizens have some understanding of science, they are likely to have to rely on professional scientists and other specialists to make public policy decisions for them (Prewitt, 1983). The democratic autonomy of ordinary citizens will therefore be affected, and it seems unlikely that the recently liberated South African society, in which the principles of democracy have been eroded for so long, will in the long-term consent to the transformation of democratic practices into - to use Roszak's metaphor (1973; cited by Prewitt, 1983) - a spectator sport. Citizens must therefore possess some degree of scientific literacy in order to become meaningfully involved in and engaged with political processes, public policy-making, and social change (Prewitt, 1983) in South Africa.

The above three arguments for the perceived need of scientific literacy in South Africa are part of the broad goals of the current democratically elected government. The Reconstruction and Development Programme (African National Congress [ANC], 1994a) - generally known as the 'RDP' - is the official,

integrated socio-economic policy framework by which the new government coordinates its plans for overall development in South Africa. The government has acknowledged the urgent need for generating competitive industries and for a science and technology policy commensurate with the long-term goals of the RDP. In the very recently published *Green Paper on Science and Technology*, a policy for a 'national system of innovation in science and technology' has been proposed in order to achieve sustainable, broad-based economic development in South Africa (DACST, 1996). Moreover, the general importance of scientific literacy in this process has been recognised: "for the national system of innovation to become effective and successful all South Africans should participate. This requires a society which understands and values science, engineering and technology and their critical role in ensuring national prosperity and a sustainable environment" (DACST, 1996, p. 84). Using the equivalent British term 'public understanding of science' (see Chapter 2), the Green Paper goes on to state that "... improving the public understanding of science and technology [is crucial], not only to get more students interested in the wonders and power of science, but also to boost the public's informed participation in political, economic and social activities" (DACST, 1996, p. 10).

As will become evident in Chapter 2, many of the reasons advanced here for the perceived importance of scientific literacy in the South African context correspond - not unexpectedly - with the major reasons commonly advanced for promoting scientific literacy in a general sense. It will also be clear from the various arguments presented above, that in this study the need for scientifically literate high-school leavers in South Africa is advanced from a particular perspective. The need is essentially - but by no means exclusively - perceived to be driven by the sustained economic success that South Africa requires to achieve in order to be able to improve the long-term quality of life of all of its citizens. Garrison and Lawwill's (1992) objection to and warning about making international competitiveness *the* as opposed to *an* end of science education is, however, salutatory, and relevant, and it is acknowledged here that the need for scientific literacy in South Africa should ultimately be based on the desire for individuals to become informed, empowered, independent, socially responsible and useful members of society, as well as contributors to the growth of national wealth.

## HISTORICAL OVERVIEW OF EDUCATION IN SOUTH AFRICA

In order to make this study, and the decisions and actions taken here, understandable and meaningful to the reader unfamiliar with the South African situation, it is necessary to place the South African education system prior to the elections in 1994 in historical and political context, and to sketch developments in education since then. This short overview of apartheid education is based on Hartshorne (1992), Molteno (1984), and Kallaway (1984a, 1991), except where indicated otherwise.

Schooling in South Africa has always been a contested terrain. However, prior to 1948 there had never been a coherently formulated education policy integrated into an overall state strategy. With the election of the National Party to power in May 1948, a focus on black schooling was introduced that was to have wide-ranging implications for the country. In 1949 and 1953 the Eiselen *Commission on Native Education* and the De Vos Malan *Coloured Education Commission* were appointed, respectively. Pursuant to their recommendations, various Acts of parliament were passed over the following two decades which resulted in the segregation into, and virtually total separation of, Bantu (i.e., African), Coloured, Indian and White education in South Africa. The most influential of these Acts was the 1953 Bantu Education Act which provided for the establishment of a centralised Department of Bantu Education. The essential function of this department has remained the same over the years, although its name has changed a number of times. In later years it was called the Department of Education and Training (DET).

Bantu education formally legislated that educational provisions be differentiated in a variety of different ways along racial lines (Kallaway, 1990). The apartheid education policy of the three decades since the mid-1950s for Africans, Coloured and Indians was

designed to control the direction of thought, to delimit the boundaries of knowledge, to restrict the lines of communication, and to curtail contact across language barriers. They aimed to dwarf the minds of black children by conditioning them to servitude ... the new system was intended to prepare black children for the subordinated positions that awaited them in such a way that they were appropriately equipped with limited skills as well as to resign themselves to their exploitation. (Molteno, 1984, p. 94)

The education provided for Africans, Coloured and Indians was thus inferior, and in the case of Africans vastly so, to that provided for Whites, and represented a denial of educational opportunity.

Parallel to these developments in education ran the establishment of so-called homelands or Bantustans. In the early 1900s, the right to own land was removed from Africans. Through legislation in 1913 and 1936 land was earmarked as African reserves, outside of which no African could acquire land without government approval (Kane-Berman, 1978). The political strategy of the Nationalist government was essentially to consolidate this process by means of establishing homelands. The purpose of these homelands was to restrict Africans - politically and territorially - to their own 'ancestral land' and to allow only sufficient numbers to live temporarily in municipal areas outside these homelands to satisfy the demands of labour in the industries of White South Africa (Kane-Berman, 1978). (This policy legislatively entrenched the notorious pass laws, influx control legislation, migrant labour practices, system of job reservation, and forced removals which are synonymous with apartheid). In 1959, the legislation enshrining the homelands policy was passed, which in the 1970s resulted in the formation of

four 'independent'<sup>4</sup> homelands (the so-called TBVC states: Transkei, Bophuthatswana, Venda, and Ciskei) and six self-governing homelands (Lebowa, Qwaqwa, KwaZulu, Gazankulu, KaNgwane, KwaNdebele) (Hartshorne, 1992).

As each territory reached the stage of having its own authority, followed by the setting up of a legislative assembly, one of the first functions that was transferred to the new authority was that of education. In the years between 1963 and 1978 this resulted in ten separate education departments hiving off from the Department of Bantu Education [i.e., the Department of Education and Training]. As each one was established, a Secretary of the department and a complete bureaucracy was set up, duplicating many, but not all, of the functions of the central department. (Hartshorne, 1992, p. 127)

Although each of these ten education departments was nominally autonomous, the DET was still responsible for African Std 10 (year 12) examinations in these homelands, except in Transkei. The DET thus influenced the various departments to continue to use DET curricula and to stay in line with the education policy in the Republic of South Africa (Hartshorne, 1992).

By the early 1980s, the racially-based and fragmented structure of education in South Africa was apparent in the existence of the 18 different departments of education (South African Institute of Race Relations [SAIRR], 1990). These departments continued to operate until recently (see below). White education was administered by a provincial department of education for each of the then four provinces (i.e., Cape, Natal, Orange Free State, and Transvaal), and Coloured and Indian education were administered by one department each. African education was administered by one of 11 departments: the DET, which administered the education of Africans in the White-designated areas of the Republic of South Africa, and the ten education departments of the four 'independent' and six self-governing homelands. In addition, the Department of National Education was responsible for a number of aspects of education (e.g., professional registration of teachers, salaries and conditions of employment of staff, the norms and standards regarding syllabuses, etc.) for all population groups in South Africa (SAIRR, 1990).

In the case of White, Coloured and Indian education, each department was responsible for the administration of the school-leaving examination at the end of Std 10 (i.e., the 'matric' exam) of its own students (SAIRR, 1990). (The examination leads to the award of a School-leaving Certificate with or

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4. Putting the word 'independent' in single quotes is meant to indicate that although the word describes a constitutional change in the status of the TBVC territories, they are not independent in the usual sense as applied to sovereign states. The concept of independence in relation to these territories is highly problematic. It is used mainly to distinguish this group of homelands from those described officially as 'self-governing', an equally problematic term. (After Hartshorne [1992])

without a Matriculation Exemption [Herman, 1995]. "Candidates who achieve the Matriculation Exemption are eligible for undergraduate studies at university, subject to additional entrance requirements which the individual universities may set" [Herman, 1995, p. 265].) In the case of White education, authority was devolved provincially, allowing each province to administer its own examinations. African matric examinations were administered by the DET and the Transkei Department of Education. The Joint Matriculation Board controlled certification and examination moderation on a national level (Hartshorne, 1992; SAIRR, 1993), and issued the matric exemptions necessary for entrance into universities and technikons (van Zyl, 1991).

After the unbanning of the ANC and a number of other political organisations in 1990, the previous South African government embarked on a programme of policy reform in education, the goal of which was a unitary education system for the whole country (SAIRR, 1993). In 1991, different models of admission criteria were introduced in White schools, providing a mechanism for allowing students of all population groups entry into previously Whites-only state schools (SAIRR, 1992, 1993). The Joint Matriculation Board was replaced by the Independent Examinations Board (IEB) in 1993 (SAIRR, 1993). On 27 April 1994, the first democratic elections were held in South Africa. By 10 May, the 'independent' and self-governing homelands had been re-incorporated into South Africa, each becoming part of one or two of the nine newly defined provinces (i.e., Eastern Cape, Orange Free State, Gauteng, KwaZulu/Natal, Mpumalanga, Northern Cape, Northern Province, North West, and Western Cape). In terms of the interim constitution agreed upon at multiparty negotiations preceding the elections, schools became non-racial. Education fell under a central Department of Education with responsibilities being devolved largely to the new provincial governments. During 1994, the Department of Education and Training and the Department of National Education were amalgamated, and the process of amalgamating the other different education administrations and homeland administrations was begun (SAIRR, 1994). In 1995, unified provincial departments of education were established, and a *White Paper on Education and Training* describing the first steps in the new policy formation for education in South Africa was published (Republic of South Africa [RSA], 1995). National matric examinations common to all students will be written for the first time at the end of 1996.

By choice, English has been the language of instruction in virtually all African schools from Std 3 (year 5) - at least in theory if not always in practice - since 1978 (Hartshorne, 1992) while in other schools (i.e., those for Coloureds, Indians, and Whites) the official language of instruction has been English and/or Afrikaans. The regulations regarding the language of instruction in all schools have, however, become more flexible recently in the light of political developments in the constitutional arena (cf., RSA, 1996).

The general disparity between the quality of science education available to Black (particularly African) and White pupils in South Africa is widely recognised (e.g., FRD, 1993; Kahn & Rollnick, 1993) and forms part of the general differential quality in the historical provision of education to pupils

of different population groups (e.g., Kallaway, 1984b). The extent of this gap in science education has recently been illustrated by Blankley (1994), who estimated the number of pupils with particular matric classifications (i.e., School-leaving certificate with or without a Matriculation Exemption) and science subjects at the end of Std 10 (year 12) as a proportion of pupils entering Sub A (year 1). He estimated that only one out of 312 African pupils starting school in 1980 matriculated with an Exemption and a pass in Physical Science as well as Mathematics in 1991 (Blankley, 1994). The comparative figures for Coloured, Indian and White pupils are about five, 50, and 60 times better, respectively (Blankley, 1994). Although these estimates do not make any allowance for pupils who drop out of school and therefore never reach Std 10, the figures nevertheless indicate very clearly that the science education available to African and Coloured pupils is extremely unsatisfactory.

## DELINEATION OF THIS STUDY

This exploratory study was conducted against the economic and educational background described above. The objective of this thesis was to assess, and to supply baseline data on, the ability of science education provided by the recent South African education system to generate scientifically literate matriculants. To this end, a scientific literacy survey was conducted amongst matriculants who must be regarded as successful final products of the education system, that is first-time entering students at tertiary educational institutions. Students participating in the survey were enrolled in a variety of different disciplines at the Universities of Cape Town, Stellenbosch and the Western Cape, and at the Cape and Peninsula Technikons.

As a systematic study of the scientific literacy of matriculants at the secondary/tertiary education interface in South Africa has hitherto not been undertaken, the necessarily exploratory nature of this study, as well as the research framework of related studies, indicated that a survey-based research design is appropriate here. "Survey research is a significant way of generating knowledge of *what is*" (Butts, 1983, p. 192), and the following factors have been noted as being among the strengths of a survey approach to identifying individuals' knowledge of, or attitudes to, scientific topics:

- i. The method, unlike small-scale studies, provides very useful information on the distribution of attitudes and knowledge in the population as a whole.
- ii. The data generated provides invaluable material to test and measure trends over time so as to observe how major events and forces influence attitudes and knowledge about specific topics.

- iii. The data generated can also show how attitudes and knowledge are demographically determined i.e., whether there are age, sex, and class differences.
- iv. It is the only means of obtaining representative data that can be used to do national or regional comparisons, which can be linked, for example, to spending on science education. (Furnham, 1992, p. 42)

All of these factors are very germane to the research problem under investigation in this study (see below), thus confirming the appropriateness of a survey approach here. It must, however, be noted from the outset that because of the non-experimental nature of this particular research design (i.e., no attempt is made to exercise experimental control), the survey approach is not suitable for obtaining insight into cause and effect (e.g., Walker & Burnhill, 1988). In this study the individual student is the unit of analysis.

The specific aims of this thesis were four-fold:

1. to construct a reliable and valid paper-and-pencil test instrument of scientific literacy;
2. to determine the level of scientific literacy of matriculants entering tertiary education for the first time;
3. to describe patterns of scientific literacy levels with respect to selected demographic and other background variables; and
4. to ascertain which background variables appear to have the most influence on determining whether matriculants are scientifically literate or not.

The thesis thus consists of essentially two phases. The first involves the text-based generation of a pool of scientific literacy test-items and the subsequent use of these items in the development of a reliable and valid criterion-referenced *Test of Basic Scientific Literacy*. The second phase involves the administration of this test to first-time entering students in a large-scale survey of scientific literacy, and entails the analysis of data and subsequent description of patterns and predictors of scientific literacy of these students.

In the following chapter, I review the extensive literature on scientific literacy and provide a conceptual overview of this concept in order to locate this study and its approach to measuring scientific literacy in a theoretical framework. In Chapter 3, I discuss the rationale for new scientific literacy test-items, outline the assessment strategy used in measuring scientific literacy, and describe the generation of the scientific literacy test-item pool. General features, as well as the ideological framework, of the text on which the items are based (i.e., *Science for all Americans*) are also described. The construction of a paper-and-pencil *Test of Basic Scientific Literacy* (TBSL), consisting of three subtests, is described in



Chapter 4. The procedures used to evaluate and select test-items for the final form of the scientific literacy test are outlined, and the validity of the test-items is assessed. The setting and validation of a performance standard for TBSL is described, and the internal consistency as well as the consistency of mastery-nonmastery classification decisions of the test with respect to scientific literacy is assessed. In Chapter 5, I describe the demographic and background variables included in the survey questionnaire of which the TBSL forms a part, and outline the administration of the scientific literacy survey to first-time entering students at the five tertiary educational institutions in the Western Cape. In addition, the final overall student sample obtained is described, and the representativeness of the sample evaluated. The level of scientific literacy of matriculants is examined in Chapter 6, and I describe patterns of scientific literacy levels with respect to selected demographic and various other background variables. In Chapter 7 logistic regression models of predictors of scientific literacy of matriculants are constructed, and I discuss the reasons for and implications of observed relationships between various background variables and scientific literacy. In the final chapter, I summarise the results of the study and make recommendations for the way forward.

### **Assumptions**

Two assumptions are made in this study: one relates to the benefit of scientific literacy, and the other is associated with the manner in which students completed the TBSL. Firstly, three justifications underpin this study with respect to the perceived need for scientifically literate matriculants in South Africa, namely the economic, decision-making, and democratic arguments (see above). As was discussed earlier, the objectives of the latter two arguments are related to the benefits of scientific literacy to individuals and to society as a whole. However, the premise of these arguments is that the scientific literacy of matriculants translates into better decision-making and social responsibility for matriculants as adults, that is scientific literacy will also serve matriculants in later life (Shamos, 1995). Secondly, it must be assumed that when answering the selected response items of the TBSL, students give answers that accurately reflect (a) their own understanding of particular science concepts and (b) that of their own position with respect to attitudes toward science.

### **Clarification of terms**

In this study, the following meaning has been attached to each of the terms listed below:

#### *Scientifically literate*

The attainment of a score above a particular cut-off point on each of the three subtest of the TBSL, on the basis of which an examinee is classified a “master” (as opposed to a “nonmaster”).

*High-school leaver*

Any person who has completed Std 10 (year 12) in any Education Department in South Africa.<sup>5</sup>

*Matriculant*

Any person who has successfully completed Std 10 (year 12) in any Education Department in South Africa,<sup>5</sup> and who has obtained a School-leaving Certificate only, or a School-leaving Certificate with either a full Matriculation Exemption or a conditional exemption, not more than two years before enrolment at a tertiary educational institution.

*First-time entering student*

A full-time student who has not previously been enrolled at any post-secondary education institution (i.e., a university, technikon, college of education, nursing or agricultural college) in South Africa and who is enrolled for the first time for a general academic or professional bachelor's degree at a university, or a first National Diploma at a technikon, before the age of 24. (Thus mature students are excluded from this study.)

An increasing level of specialisation is denoted by the progression from *high-school leaver* to *matriculant* to *student*, and the above terms are used to describe greater or lesser levels of applicability or generalisation of, for example, arguments, findings, or implications in this study.

**SCIENTIFIC LITERACY-RELATED RESEARCH IN SOUTH AFRICA**

By way of introduction it is appropriate to briefly outline how the term 'scientific literacy' entered the general educational discourse in South Africa. In 1978 the South African Association of Teachers of Physical Science (SAATPS) organised a National Science Education Workshop debating how science education in South Africa could best be improved. The conclusions and recommendations reached during this workshop addressed all three dimensions of Miller's (1983) definition of scientific literacy (SAATPS, 1978), and it is very probable that this document represents one of the first references to scientific literacy in South Africa - at least in spirit. The *HSRC Investigation into Education*, the so-called de Lange Commission, which was convened in response to the education crisis precipitated by the 1976 Soweto uprising (e.g., Kane-Berman, 1978), adopted some of the recommendations contained in the SAATPS document and mentioned a lack of "scientific and technological literacy" in the context of

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5. Including all former 'independent' and self-governing homelands.

possible factors related to the unpopularity of Physical Science as a science subject in high-school (Human Sciences Research Council, 1981, p. 32).

Scientific literacy is not a well-developed area of research in South Africa, and investigations with respect to this concept have taken essentially two directions since the middle 1980s. Firstly, research efforts concentrated on the promotion of scientific literacy of secondary school pupils through informal science teaching (e.g., Maarschalk 1986, 1988). Informal science teaching was defined as "... teaching that is given in situations in life that come about spontaneously, for example within the family circle, the neighbourhood and so on" (p. 355), and the investigation of such teaching was believed to examine the "... roots and sources of a society's science education ..." (Maarschalk, 1986, p. 355). Using interviews and questionnaires in the form of a three-day diary, Maarschalk and his colleagues showed, for example, that the scientific literacy of secondary pupils studying physics could be improved by exposure to supplementary informal science activities such as discussions about rockets and space flight (Maarschalk & Strauss, 1992). General results of Maarschalk's Scientific Literacy Research Project suggested that formal science teaching should be augmented with nonformal and informal science teaching, and that "... a more informal and less rigid approach in science teaching will promote scientific literacy" (Maarschalk & Strauss, 1992, p. 40). As they have pointed out, the general conclusion that less and not more teaching of science content was required in South African schools in order to increase scientific literacy, blends perfectly with the educational aims of the American Association for the Advancement of Science's *Project 2061* (Maarschalk & Strauss, 1992).

The second direction of research in scientific literacy in South Africa is related to initial attempts to replicate scientific literacy surveys carried out elsewhere (see Chapter 3). Although various studies have reported that a large proportion of adults in the United States (e.g., Miller, 1987; Miller, 1989a) and Britain (e.g., Lucas, 1987ab, 1988; Durant, Evans, & Thomas, 1989) has a very limited knowledge and understanding of science, a survey of the scientific literacy of a representative sample of the South African public - with respect to all population groups - has yet to be undertaken.<sup>6</sup> In 1991, Pouris (1991b) conducted a survey amongst 1300 urban adult White South Africans. The study investigated these adults' knowledge of facts concerning physics and the earth sciences, beliefs about human origins, public attitudes toward astrology, and beliefs relating to the benefits and harmful effects of science in everyday life. Results showed that this sample of the South African public fared similarly to Americans and Britons on the physics and earth science items. However, a much smaller proportion of South African adults believed that humans evolved from animals, and that astrology has no scientific basis (Pouris, 1991b). Compared to the sample from the United States and Britain, approximately similar proportions of South African adults felt that science makes their lives easier, healthier, and more

6. It is interesting to note that a survey of 'human sciences literacy' has recently been conducted amongst a representative sample of South African adults (see Prinsloo, 1994). Some literacy recommendations made in *Science for all Americans* with respect to the social sciences have been used in this survey.

comfortable. However, relatively fewer South Africans believed that the world is better off because of science (Pouris, 1991b).

A similar scientific literacy survey was conducted amongst a cross-section of a national sample of 400 White and 400 Black urban South African teenagers between the ages of 13 and 20 years (Pouris, 1993). On the physical and earth science questions, White teenagers performed better than White adults, English-speaking teenagers out-performed other language groups, and, irrespective of population group, males performed better than females (Pouris, 1993). Roughly similar proportions of Black and White respondents agreed with the idea of evolution, although agreement of Afrikaans-speaking teenagers with this idea was markedly lower than for other language groups (Pouris, 1993). Overall, Black teenagers were the most optimistic that science will solve social problems and cure mental illness (Pouris, 1993).

The study of Glover (1992) represents the only investigation of scientific literacy directly concerned with formal education in South Africa. His research was related to the Science Education Project (SEP), a non-governmental organisation which focuses on curriculum innovation and assists mainly African teachers in poorly resourced classrooms to teach science effectively through the use of laboratory kits. The skills and attitudes that SEP attempted to develop through its particular teaching approach included characteristics of scientific literacy, and examined teacher-pupil interactions in 'SEP science classrooms' in the Ciskei, and recorded 'SEP' and 'non-SEP' pupils' attitudes toward science in Transkei (Glover, 1992). (Ciskei and Transkei were formerly 'independent' - largely rural - homelands [see above].) The study took place against a general backdrop of political unrest and upheaval in Black schools country-wide, and it was concluded that

... while elements of education for scientific literacy did exist in some classrooms, the intrusion of political events and the effect of culture and language mitigate against the success of science education for scientific literacy. Whereas SEP might have equipped teachers conventionally to facilitate scientific literacy, the students do not appear to be in a frame of mind to receive such messages. (Glover, 1992, p. i)

In previous work, Glover (1990) made an attempt to bring world trends to bear on the aims of science education in South Africa. He suggested that the concept of scientific literacy provides the basis for a reconceptualised goal of science education in South Africa - "as in any modern democracy" (p. 157). In order to achieve this, he proposed a Science-Technology-Society approach, and suggested that the science curriculum should be organised around problem-solving skills and real-life issues, as well as around personal and community decision-making. "By having as its aim a scientifically ... literate population science education becomes proactive, value-laden and self-consciously cultural, offering the opportunity for an education through science rather than merely an education in science" (Glover, 1990, p. 156).

## DISSENTING OPINIONS

Although there is widespread belief that scientific literacy (and by implication science education) is a 'good thing', there are also a small number of dissenting voices that include Chapman (1991), Laetsch (1987), and Shamos (1995). While Chapman challenges the dominant position of science education in the National Curriculum in Britain, both Shamos and Laetsch focus exclusively on the United States and believe that the attainment of scientific literacy by the general public is essentially an idealistic and impractical ideal. However, Chapman's theme of the 'overselling' of science also runs through these two positions.

Chapman (1991) examines more carefully the " 'institutional truth' embodied in the National Curriculum ... that 'science' is so important that all future citizens should have it delivered to them throughout their years of compulsory schooling" (p. 48). He argues, for example, that in a post-industrial society in which employment is forecast to grow in the management and service sectors rather than in the industrial (i.e., manufacturing) sectors of the economy, compulsory education in the sciences is not of direct employment relevance to young people. Chapman (1991) proposes a 'systems approach' to science and technology and believes that developments in technology reduce, rather than increase, the need for individuals to know more about technology. The problem of the 'science for citizenship' reason for promoting compulsory science education, his argument runs, lies with a "global economy rooted in free-market competition and consumption" (p. 58). In the context of such an economic system, "better science and technology actually makes it easier for the rich to exploit the poor" (Chapman, 1991, p. 58). In order to promote 'science for citizenship', Chapman (1991) believes a perspective of world rather than national citizenship to be more appropriate.

In comparison to Chapman, Laetsch and Shamos take a decidedly more optimistic view of the value of science to individuals. Laetsch (1987) provides a contrary view for some of the claims made for scientific literacy and suggests that the reasoning supporting a number of the arguments used to promote scientific literacy is flawed. Although Laetsch (1987, p. 10) generally acknowledges the value of scientific literacy to society and believes that "scientific literacy helps us to understand ourselves and our environment and the relationship between the two ...", he differs with the conventional multi-faceted view on why scientific literacy should be developed. He argues that "generic literacy, not necessarily a specific form is the goal ..." (p. 8), and believes that an "... understanding of science for its own sake is ample and sufficient reason for promoting scientific literacy" (p. 9): "it makes our lives far richer than is possible without a knowledge of the surrounding world" (p. 9).

Shamos (1995) argues that the attainment of scientific literacy by the general public is not merely a matter of formal education, firstly, because becoming literate in science is no guarantee for remaining literate, and, secondly, because there is not "... widespread acceptance by the public of the idea that

becoming and remaining literate in science may actually be in one's self-interest ..." (p. 215). Accordingly, he reformulates the goal of science education to that of achieving science awareness (Shamos, 1995). This would allow, so the argument runs, the public and public officials to appreciate science and technology, and thus have "the public participate directly in the decision-making process on societal issues having a scientific base, issues that are actually based for the most part in technology ..." (Shamos, 1995, p. 216). He therefore suggests that science should be presented as a cultural imperative (i.e., in such a way to develop an appreciation and awareness of the scientific enterprise), as a practical imperative (i.e., focusing on the benefits of science and technology to an individual's personal health and safety), and in a manner that emphasises "... the *proper* use of scientific experts ..." (Shamos, 1995, p. 217). Shamos believes that science curricula need to change in order to emphasise the process instead of the content of science, and a number of guidelines are proposed for such a shift in curricular emphasis.

While the contrary opinions of science and scientific literacy held by Chapman (1991), Laetsch (1987), and Shamos (1995) are acknowledged, it must also be recognised that all of these perspectives were formed in the context of developed and industrialised countries having mature economies (cf. Schreuder, 1994; Spargo & Laugksch, 1994). South Africa, however, is generally regarded as having a mixture of First and Third World characteristics and, as has been outlined earlier, is believed to be still far from having - in world terms - a well-established manufacturing industry. South Africa still needs to reach the widespread level of wealth and social progress displayed by developed countries, and in a science- and technology orientated world the significance of science and scientific literacy in this process is likely to be substantial.

Judging by the extensive literature on this topic, there is much evidence that the concept of scientific literacy is widely regarded as important in a national and educational context. In the next chapter, this literature is reviewed and a conceptual overview of scientific literacy is provided.



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## Chapter Two

### SCIENTIFIC LITERACY: A CONCEPTUAL OVERVIEW

The term 'scientific literacy' was coined in the late 1950s, and most probably appeared in print for the first time when Paul Hurd of Stanford University (Hurd, 1958) used it in a publication entitled *Science literacy: its meaning for American schools* (DeBoer, 1991; Roberts, 1983). Since then, scientific literacy has become an internationally well recognised educational slogan, buzzword, catchphrase, and contemporary educational goal. Scientific literacy "stands for what the general public ought to know about science" (Durant, 1993, p. 129), and "commonly implies an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas" (Jenkins, 1994, p. 5345). The term is usually regarded as being synonymous with 'public understanding of science', and while 'scientific literacy' is used in the United States, the latter phrase is more commonly used in Britain, with 'la culture scientifique' being used in France (Durant, 1993).

### THE HISTORICAL CONTEXT

Interest in and concern about elements of scientific literacy go back at least to the beginning of this century (Shamos, 1995), and Hurd (1990) contends that the concept of scientific literacy as it relates to science education may be traced as far back as to Sir Francis Bacon in the 1600s. Because of the emphasis in the present study of scientific literacy in a modern context, I focus here only on the period after World War II, specifically on the years following the late 1950s. A brief historical overview of these periods is helpful in placing the discussion of scientific literacy as a concept in context. For a fuller historical account of the scientific literacy movement the reader is referred to Shamos (1995).

The impetus for interest in scientific literacy during the late 1950s is likely to have been the concern of the American science community about public support for science for a response to the Soviet launch of Sputnik. Waterman (1960) wrote in a review of the first ten years of the U.S. National Science Foundation of the recognition that "progress in science depends to a considerable extent on public understanding and support of a sustained program of science education and research" (p. 1349). At about the same time, Americans - again sparked by the space race - became concerned about whether their children were receiving the kind of education that would enable them to cope with a society of increasing scientific and technological sophistication (Hurd, 1958). Increasing the level of scientific literacy amongst Americans was seen as a strategy for effectively addressing both of the above concerns (Hurd,



1958; Waterman, 1960). Roberts (1983) reviewed the period from the 1950s to the late 1970s, and the conclusions reached about scientific literacy as a concept in those years are based on this review.

Given the important dual context of support for science and science education, numerous authors began to promote various aspects associated with scientific literacy (e.g., references cited in DeBoer [1991] and Roberts [1983]). Roberts (1983) characterised the years from about 1957 to 1963 as the “period of legitimation” (p. 25) of the concept. The individuals advocating scientific literacy, however, did not always provide a clear definition of what they meant by this concept. The initial period was thus followed by a “period of serious interpretation” (Roberts, 1983, p. 26) in which multiple and diverse meanings of scientific literacy became apparent (DeBoer, 1991; Roberts, 1983; see also, for example, references cited in Pella, O’Hearn, & Gale [1966]). A number of attempts at consolidating scientific literacy as a concept were made (e.g., Pella, 1976; Agin, 1974), after which a period of further interpretation ensued (Roberts, 1983). However, Gabel (1976, cited in Roberts, 1983) showed in his work on a theoretical model of scientific literacy based on a large dataset of interpretations of the meaning of scientific literacy, to what extent this concept “has had so many interpretations that it now means virtually everything to do with science education” (Roberts, 1983, p. 22). The interpretations of scientific literacy as a concept had reached a point of maturity and had “come to be an umbrella concept to signify comprehensiveness in the purposes of science teaching in the schools” (Roberts, 1983, p. 29).

As the literature review by Roberts (1983) concluded, the period of the late 1970s and early 1980s was characterised by a multitude of varied definitions and interpretations of scientific literacy, and a persistent lack of consensus diminished the usefulness of this concept (Graubard, 1983). At about the same time, the United States was facing two important challenges. The first was related to the emergence of the economic power of Japan and other Pacific rim countries (i.e., South Korea, Singapore, Taiwan, etc.) and a general belief that America’s international economic competitiveness - and thus its industrial leadership - was on the wane (e.g., Bloch, 1986). Science and technology were seen as the fundamental basis for economic progress (e.g., Bloch, 1986; Lewis, 1982), and it was therefore inevitable for America’s science policy to come under the spotlight. The second challenge was related to the declining research base in science and engineering in the U.S. (e.g., Bloch, 1986), and to America’s poor standing in international comparisons of science achievement (see, for example, references cited in Appendix B of AAAS [1989]; Wirszup [1983/84]). At this time a widely held belief about the existence of a crisis in science education prevailed (e.g., Champagne & Klopfer, 1982; Yager, 1984; but, for a contrary view, see Shamos [1988]), particularly after the National Commission on Excellence in Education (1984) report *A Nation at Risk*.

Due to perceived threats to the economic competitiveness of the United States and the crisis that American science education was seen to be in, a reawakened interest in scientific literacy developed in the early 1980s (Prewitt, 1983; Graubard, 1983). Since this period, the scientific literacy of adults has received regular attention in the United States and elsewhere (e.g., Miller, 1992). The social and cultural

relevance of science in a scientific and technological society (Chen & Novik, 1984; Shymansky & Kyle, 1992) - with its resultant 'socio-civic' (Hlebowitsh & Hudson, 1991) or social responsibility (Ramsey, 1993) focus on science education reform - has also increasingly received attention through the concept of scientific literacy. In recent years, policy statements related to science education have thus been replete with references to scientific literacy as a goal (Atkin & Helms, 1993; Jenkins, 1992).

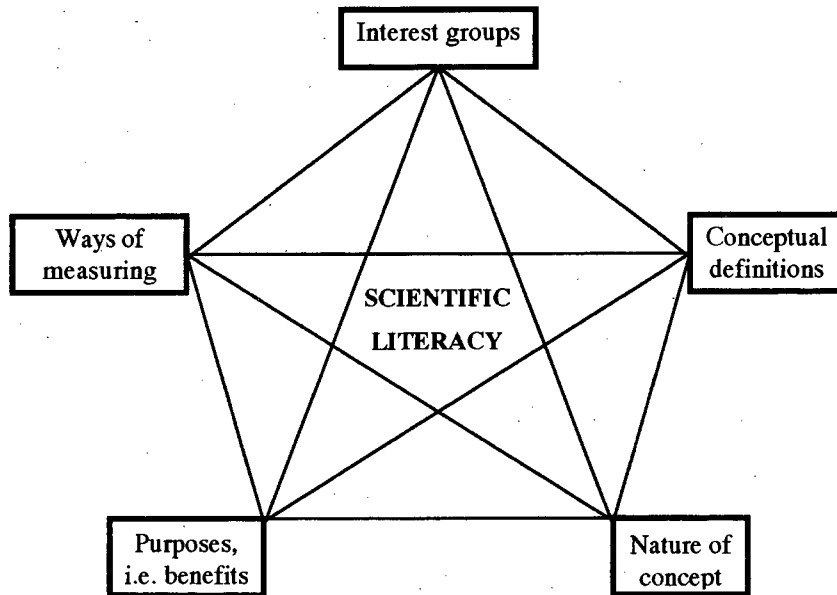
In many ways, therefore, scientific literacy is an old educational slogan (Roberts, 1983), and the concept has generated much interest over the last four decades. Consequently there exists a substantial and diverse literature related to this concept (e.g., Baker, 1991; DeBoer, 1991; Garfield, 1988; Roberts, 1983; Layton, Jenkins, & Donnelly, 1994). For example, based on an ERIC search, over 330 journal articles, conference papers, project descriptions, project reports, and editorials related to scientific literacy were found to have appeared in the literature between 1974 and 1990, with the vast majority being published after 1980. In order to obtain a better understanding of the concept of scientific literacy and its associated difficulties, a conceptual overview is described next.

## CONCEPTUAL OVERVIEW

Despite (or maybe because of) the attention that scientific literacy has received over the years, this concept is frequently recognised as being controversial (Jenkins, 1990, 1994). Why should this be so? The fact that the term scientific literacy can be thought of as belonging to a class of terms like *liberty*, *justice*, and *happiness*, that we assume to contain simple and desirable qualities but that under closer examination become vastly more complex and often elusive (cf., Venezky, 1990), will have undoubtedly contributed to its controversial nature. Inspection of the extensive literature on scientific literacy suggests, however, that there are a number of different factors which can influence interpretations of scientific literacy. These factors include the number of different interest groups that are concerned with scientific literacy, different conceptual definitions of the term, the relative or absolute nature of scientific literacy as a concept, different purposes for advocating scientific literacy, and different ways of measuring it (Figure 2.1). Each factor consists of different positions or facets, and it is postulated here that combinations of different facets of each of the five individual factors result in permutations of varying interpretations and perceptions of scientific literacy. These different interpretations result in scientific literacy appearing to be an ill-defined and diffuse - and thus controversial - concept.

The different positions and perceptions available under each of the above factors are now described below. The four broad categories of interest groups concerned with scientific literacy are sketched first, and thereafter I review the different conceptual definitions of scientific literacy that have been proposed. The relative or absolute nature of the concept is described next, and the benefits alleged to accrue from

scientific literacy are discussed thereafter. Finally, I give a brief overview of the different research frameworks employed to measure scientific literacy.



**Figure 2.1.** A conceptual overview of scientific literacy.

### Interest groups

Although scientific literacy is widely regarded as being of general educational importance, at least four broad categories of workers involved in scientific literacy are discernible. These categories or ‘interest groups’ are characterised by a shared core theme of interest in the promotion of scientific literacy in the whole or in a particular section of the wider community.

The first interest group that can be identified is the science education community, which is concerned with the nature (i.e., purpose), performance, and reform of existing educational systems (see, for example, Champagne & Newell, 1992; Jenkins, 1992; Kyle, 1995ab). This group’s involvement in scientific literacy is motivated by issues related to (a) the goals of science education (i.e., why teach science and what form should the science content take); (b) how personal skills, attitudes, and values implied by the goals are successfully incorporated into the science curriculum, and effectively taught by teachers; (c) the quality and nature of resources required to achieve these goals efficiently (e.g., text books); and, (d) appropriate measures of assessment to ascertain to what extent the goals for science

education have been met. Associated with this interest group would also be science curriculum development groups, as well as professional science education associations. This first interest group is therefore mainly concerned about the relationship between formal education and scientific literacy, and the group has a specific focus on secondary, but increasingly also on primary and tertiary, education.

The second interest group includes social scientists and public opinion researchers concerned with science and technology policy issues (see, for example, Miller, 1992). This interest group is essentially concerned about the extent of the general public's support for science and technology, as well as the public's participation in science and technology policy activities. Pertinent fields of inquiry for this category of researchers are thus related to the identification of the individual's sources of scientific and technical information; measuring the public's scientific knowledge base and perceptions of the limitations of science, as well as measuring the public's attitude toward science and technology in general and toward selected current policy issues in particular (see, for example, National Science Board [NSB], 1993).

The third interest group includes sociologists of science and science educators employing a sociological approach to scientific literacy. These researchers are concerned with the construction of authority with respect to science (i.e., organisational forms of ownership and control of science), or 'knowledges in context' as Wynne (1991) has put it. Fields of enquiry for this category of researchers are related to how individuals in everyday life interpret and negotiate scientific knowledge; how social access, trust, and motivation are linked to public uptake of and support for science; and how "... members of the public ... monitor sources of scientific information, judge between them, keep up with shifting scientific understandings, distinguish consensus from isolated scientific opinion, and decide how expert knowledge needs qualifying for use in *their* particular situation" (Wynne, 1991, p. 117).

The fourth interest group that can be identified is the in- and non-formal formal (cf., Lucas, 1991; Maarschalk, 1988) science education community, and those involved in general science communication. The combined group thus consists of those professionals that provide educational and interpretative opportunities for the general public to better familiarise itself with science (see, for example, Durant, 1992; Quin, 1993), in addition to those who report science as 'news' (see, for example, Nelkin, 1987) and write about science in general (see, for example, Lewenstein, 1989; McRae, 1993). These professionals include relevant personnel involved in science museums and science centres, botanical gardens and zoos, as well as members of creative teams involved in science exhibitions and science displays. Science journalists and writers, and relevant personnel involved in science radio programmes and television shows complete this interest group.

The above interest groups also differ with respect to the 'audiences' that form the focus of the groups' attention. The science education group focuses largely on the scientific literacy of children (i.e., at primary school) and adolescents (i.e., at secondary school), whereas the social scientist and sociologist of science interest group focuses on the scientific literacy of out-of-school individuals (i.e., adults). The

fourth interest group, however, focuses on promoting the scientific literacy of a combination of the three audiences identified above, that is children, adolescents, as well as adults. This fourth group will not be considered further here, as it relates only indirectly to the research that is being reviewed here.

### **Conceptions of scientific literacy**

During the course of the development of the concept, a number of different positions on, as well as interpretations and definitions of, scientific literacy have been proposed. Some of these interpretations were based on research, and others were based on personal perceptions about the characteristics of a scientifically literate individual and what such an individual should be able to do. Below, I describe commonly cited definitions and interpretations of scientific literacy in more or less chronological order of publication.

In the Rede Lecture at Cambridge University in 1959, C. P. Snow suggested that there was a sharp division between literary intellectuals on the one hand, and scientists on the other (Snow, 1962). This division, in his view, represented a gulf of mutual incomprehension, hostility, and dislike, and, most importantly, resulted in a lack of understanding between 'the two cultures'. He saw the development of these two separate cultures as counterproductive, especially in a democratic society, and suggested that individuals in a rapidly changing scientific and technological world cannot be regarded as "learned" unless they have some grounding in both cultures.

The work by Pella et al. (1966) represents one of the earliest attempts to provide an empirical basis for the definition of scientific literacy. Pella and his colleagues identified 'referents' (i.e., common factors) of scientific literacy and their frequency of occurrence in 100 carefully and systematically selected papers published between 1946 and 1964. They concluded that

the scientifically literate individual presently is characterized as one with an understanding of the (a) basic concepts in science, (b) nature of science, (c) ethics that control the scientist in his work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities and (f) difference between science and technology. (Pella et al., 1966, p. 206)

The frequency of occurrence of these 'referents' in the literature revealed that the first three characteristics were more important than the latter three (Pella et al., 1966).

Pella's work on the delineation of scientific literacy as a concept was extended by Showalter (1974, cited in Rubba & Anderson, 1978), who integrated 15 years of relevant literature into a seven dimension definition of scientific literacy:

- I. The scientifically literate person understands the nature of scientific knowledge.
- II. The scientifically literate person accurately applies appropriate science concepts, principles, laws, and theories in interacting with his universe.
- III. The scientifically literate person uses processes of science in solving problems, making decisions, and furthering his own understanding of the universe.
- IV. The scientifically literate person interacts with the various aspects of his universe in a way that is consistent with the values that underlie science.
- V. The scientifically literate person understands and appreciates the joint enterprises of science and technology and the interrelationship of these with each and with other aspects of society.
- VI. The scientifically literate person has developed a richer, more satisfying, more exciting view of the universe as a result of his science education and continues to extend this education throughout his life.
- VII. The scientifically literate person has developed numerous manipulative skills associated with science and technology. (Showalter, 1974, cited in Rubba & Anderson, 1978, p. 450)

The feature of this particular work was that it defined scientific literacy “with a degree of specificity not found in other definitions of this concept” at that time (Rubba & Anderson, 1978, p. 450).

Shen (1975a) suggested three categories of scientific literacy, namely practical, civic, and cultural scientific literacy. These categories were acknowledged to be not mutually exclusive, but were nevertheless distinct with respect to objective, audience, contents, format, and means of delivery. By practical scientific literacy, Shen (1975a, p. 46) meant the “possession of the kind of scientific knowledge that can be used to help solve practical problems”, that is knowledge that addresses the most basic human needs related to food, health, and shelter (Shen, 1975ab). This category of scientific literacy was seen as being of particular importance in, but by no means confined to, developing countries, where “a few pieces of essential scientific information can mean the difference between health and disease, life and death” (Shen, 1975a, pp. 46-47). (See Kalra [1990] for a recent attempt to translate such practical scientific literacy into an appropriate curriculum for the rural youth with limited schooling in India.) In industrialised countries, on the other hand, practical scientific literacy could well be useful in consumer protection efforts (Shen, 1975b). Shen (1975a) believed civic scientific literacy to be the cornerstone of informed public policy. He suggested that the aim of this category of scientific literacy was to enable citizens to become sufficiently aware of science and science-related public issues in order for the average

citizen to become involved in the decision-making process related to such issues as, for example, health, energy, natural resources, food, the environment, and so forth. Like Snow (1962) and others (see below), Shen (1975a) believed such an involvement to be necessary for democratic processes to operate in a technological society. "Cultural scientific literacy is motivated by a desire to know something about science as a major human achievement" (Shen 1975a, p. 49). Although he saw this category of scientific literacy to be achieved by only a comparatively small number of individuals because its reach would not extend much beyond the intellectual community (Shen, 1975b), he believed this category to be important and influential because it would preferentially reach current and future opinion-leaders and decision-makers (Shen, 1975a). (It is interesting to note that in concluding remarks Shen (1975a) called for a "vigorous program of survey research to determine the effectiveness of selected science-literacy projects" (p. 51), and that he made suggestions about how in such research the parameters to be measured would differ for various categories of scientific literacy.) The kinds of categorisations of scientific literacy provided by Shen's interpretation of the concept can be extended to accommodate a range of functional scientific literacies related to different contexts (Jenkins, 1994).

An example of such an extension is Branscomb's (1981) proposed conceptualisation of scientific literacy. She examined the Latin root of 'science' and 'literacy' and defined the concept as "the ability to read, write, and understand systematized human knowledge" (p. 5). She identified eight different categories of scientific literacy: (a) methodological science literacy, (b) professional science literacy, (c) universal science literacy, (d) technological science literacy, (e) amateur science literacy, (f) journalistic science literacy, (g) science policy literacy, and (h) public science policy literacy (Branscomb, 1981). Each of these scientific literacies is related to a particular context, such as, for example, that of the professional scientists going about his or her work (professional science literacy); the average citizen understanding and coping with natural phenomena of daily life (universal science literacy); and that of the political representative making public decisions requiring an understanding of scientific data or predictions of probable consequences (science policy literacy).

As was mentioned in the discussion of the historical context of scientific literacy (see above), issues related to science and technology, science policy, and the role of science in society were of concern in the United States in the early 1980s. In a 1983 special issue of *Daedalus*, the journal of the American Academy of Arts and Sciences, a number of authors gave their opinion on scientific literacy and the challenges facing America. Jon Miller's paper on a conceptual and empirical review of scientific literacy was influential, as he not only proposed a multi-dimensional definition of scientific literacy, but also suggested ways of measuring scientific literacy. In addition, he presented data of adult levels of scientific literacy in the United States based on his framework. Miller (1983) contended that "in a democratic society, the level of scientific literacy in the population has important implications for science policy decisions" (p. 29). He examined how the meaning of the term had changed in the United States since the latter part of the last century, and reviewed the various attempts to measure individual components of

scientific literacy since the 1930s. On the basis of these considerations, Miller (1983) defined scientific literacy in the “contemporary situation” (p. 31) (i.e., in today’s scientific and technological society) as consisting of three dimensions: (a) an understanding of the norms and methods of science (i.e., the nature of science), (b) an understanding of key scientific terms and concepts (i.e., science content knowledge), and (c) an awareness and understanding of the impact of science and technology on society. Coming after Gabel’s (1976) findings of the late 1970s that scientific literacy was too loose a term and with too many interpretations to be of any use, Miller’s (1983) paper proposing a particular, bounded, and multi-dimensional model of scientific literacy comprised an important consolidation of this concept.

Arons (1983) enumerated 12 attributes of a scientifically literate individual that he considered important. He included Miller’s (1983) three dimensions in the list of attributes, but emphasised the intellectual abilities - or ‘habits of mind’ - required of scientifically literate persons. For example, Arons (1983, pp. 92-93) contended that such individuals will possess the ability (a) to recognise that “scientific concepts are invented or created by acts of human intelligence and imagination...”; (b) to “comprehend the distinction between observation and inference...”; (c) to comprehend “...the deliberate strategy of forming and testing hypotheses”; and (d) to “...recognize when questions such as ‘How do we know...? Why do we believe...? What is the evidence for...?’ have been addressed, answered, and understood, and when something is taken on faith”. (Linked to Arons’ [1983] emphasis is a portrayal of scientific literacy in which scientifically literate individuals are able to correctly apply scientific knowledge and reasoning skills to solving problems and making decisions in their personal, civic, and professional spheres [e.g., Brickhouse, Ebert-May, Wier, 1989; cf., Laetsch, 1987]. These issues are related to the benefits or purpose for promoting scientific literacy, and will be discussed in a later section.)

Hazen and Trefil (1990) believe that there is a clear distinction between *doing* and *using* science. They define scientific literacy as “the knowledge you need to understand public issues. It is a mix of facts, vocabulary, concepts, history, and philosophy” (p. xii). Such a conceptual definition of scientific literacy is linked to Hirsch’s (1987) concept of ‘cultural literacy’ which he described as the “oxygen of social intercourse” (p. 19). Hirsch’s premise is that effective communication between two parties (whether between individuals or groups) requires an estimate of how much relevant information can be taken for granted in the other party, as this assumed background knowledge reflects a necessary familiarity of the current mainstream culture, whether in language, history, or science. A store of shared knowledge - ‘cultural literacy’ - is therefore important in national communication such as, for example, reading newspapers and magazines, communicating with elected representatives, or following debates about public issues. Hirsch together with two colleagues identified about 5000 terms and phrases that in their view, as well as being validated by reviewers, constitute the contents of cultural literacy in the social and natural sciences (Hirsch, Kett, & Trefil, 1988).

Hazen and Trefil (1990) thus see scientific literacy in a similar manner, and believe that scientifically literate individuals should be able to place news of the day about science in a meaningful context. They



describe 18 general principles of science that cover a range of topics from absolute zero to X-rays (Hazen & Trefil, 1990). (Brennan's [1992] list of definitions of about 650 science terms and topics represents a similar attempt to provide the necessary vocabulary to follow public debates involving science- and technology-related issues.) The distinguishing feature of the above conceptions of scientific literacy is the emphasis on the required content knowledge in science, i.e. Miller's second dimension of scientific literacy (Shamos, 1995).

Shamos (1989) proposed a conception of scientific literacy consisting of three forms, "...which build upon one another in degree of sophistication as well as in the chronological development of the science-orientated mind" (Shamos, 1989, p. 115). The first form, that is 'cultural scientific literacy', is that proposed by Hirsch (1987), which was described above. It is the simplest of the three forms of scientific literacy, and in Shamos' view represents the level of scientific literacy held by most educated adults who believe they are reasonably literate in science (Shamos, 1989). The second form, 'functional scientific literacy', requires that the individual not only has a command of a scientific vocabulary - a "scientific lexicon" (p. 116) - but also that the individual be able to converse, read, and write coherently in a non-technical but meaningful context (Shamos, 1989). An important difference between these forms of scientific literacy is that the first form is passive (e.g., recognition of science-based terms used by the media), whereas the second is more active. A functionally scientifically literate individual would thus not only be able to read and comprehend a science-based newspaper article, but would also be able to communicate the substance of that account to a third party (Shamos, 1989). The third form and level of scientific literacy - 'true scientific literacy' - is the most difficult to attain, as, in addition to the previous forms, it involves knowing something about the scientific enterprise. Such an individual

understands (or is at least aware of) some of the major conceptual schemes (the theories) that form the foundations of science, how they were arrived at, why they are widely accepted, how we make order out of a random universe, and the role of experimentation in science. This individual also understands the elements of the so-called 'scientific method', of proper questioning, of analytical and deductive reasoning, of logical thought processes, and of reliance upon objective evidence. (Shamos, 1989, p. 116-117)

Shamos (1989) concedes that this is a difficult and demanding level to obtain, and that true scientific literacy is likely to be out of reach for most members of society - as in the case of most highly specialised knowledge. (For a related point, see Lévy-Leblond [1992].)

A perspective of scientific literacy different to the ones encountered thus far is aptly described as 'science for specific social purposes' (e.g., Layton, Davey, & Jenkins, 1986; Layton, Jenkins, Macgill, & Davey, 1993). It represents a functional view of scientific literacy in which the meanings and social uses which science has for members of the adult public are explored (Layton et al., 1986). This interpretation

of scientific literacy contends that members of the public are not passive 'consumers' of science but that 'usable' scientific knowledge usually needs to be reworked and put into context (Layton et al., 1993). "Scientific knowledge is not received impersonally, as the product of disembodied expertise, but comes as part of life, among real people, with real interests, in a real world" (Ziman, 1991, p. 104). How the public perceives and uses scientific knowledge is therefore not only related to the public's understanding of the formal content of scientific knowledge and the methods and processes of science, but also with "the forms of institutional embedding, patronage, organisation and control of scientific knowledge" (Wynne, 1992, p. 42).

Issues raised by this particular interpretation of scientific literacy, as well as those raised by the other definitions of scientific literacy described above, are related to the nature of the concept, the purpose of scientific literacy, and how scientific literacy should be measured. Each of these issues will now be discussed separately.

### **The nature of the concept**

In order to describe and analyse how the various definitions and interpretations of scientific literacy impact on the general notion of scientific literacy, an attempted summary scheme follows. This scheme provides a framework that highlights common and implied features of previously suggested definitions of scientific literacy. The framework is based on different interpretations of the word 'literate', as well as on the nature of knowledge implied by each definition. This approach to classifying different definitions of scientific literacy borrows from Venezky's (1990) work in general literacy.

The term 'literacy' is usually interpreted as the ability to read and write. However, extensions of this term to, for example, computer literacy, cultural literacy, political literacy, and, of course, scientific literacy, suggest that semantic aspects of this term are very important in such extensions (Kintgen, 1988). Although authors generally use the term 'literacy' in its descriptive sense, it is the evaluative sense of the term - the mastery of a body of knowledge - that provides an understanding of the intended meaning (Kintgen, 1988). Three different interpretations and uses of 'literate' are considered here: literate as learned, literate as competent, and literate as able to function minimally in society.

The word *literate* derives from the Latin term *litteratus* (Clanchy, 1979), and, as Kintgen (1988) and Venezky (1990) have pointed out, the ability level of a *litteratus* has changed over the centuries. The initial, classical meaning of the word at the time of Cicero did not describe a person who could read Latin, but one who was learned (Clanchy, 1979). The *Oxford English Dictionary* (1989, Vol. 3, p. 604) defines 'competent' as "adequate or sufficient in quality or degree", and this term thus describes an intermediate level of ability between mastery and non-mastery. The third use of literate is taken from Miller (1989b) who, in discussing the relative nature of literacy, defined it as "the minimal acceptable level of knowledge or skills required to function in some set of roles in a specific society" (p. 4). The

roles he selected to be important in the context of scientific literacy in a contemporary society were those of a consumer and citizen (Miller, 1989b).

Nine of the 11 definitions and interpretations of scientific literacy described in the previous section have been classified using the three interpretations of the word 'literate' (Table 2.1). The two definitions of the concept based on criteria of scientifically literate individuals compiled from the literature (i.e., those of Pella et al. [1966] and Showalter [1974]) were excluded, as these definitions did not convey the context in which the original authors had identified the criteria.

**Table 2.1.** Classification of various interpretations of the concept of scientific literacy according to three implied interpretations of the word "literate".

Author	"learned"	"competent"	"able to function min. as consumers and citizens"
C. P. Snow (1962)	X		
Shen (1975ab)			
Practical scientific literacy			X
Civic scientific literacy			X
Cultural scientific literacy	X		
Branscomb's (1981) categories	X		X
Miller (1983)			X
Arons (1983)	X		
Hirsch (1987)		X	
Hazen & Trefil 1990)		X	
Shamos (1989)			
Cultural scientific literacy		X	
Functional scientific literacy		X	
True scientific literacy	X		
Layton et al. (1986, 1993)			X

In order to be able to place the various interpretations of scientific literacy in one or other literate category, an additional classification criterion was required so that more meaningful distinctions between the definitions could be made. This criterion was related to the uses that the proposed scientific literacy attributes were required to be put. When moving across the literate categories from 'learned' to 'function in society', an increasingly greater emphasis is placed on being able to carry out a task with the acquired scientific literacy attributes, and on being able to use these attributes to cope in everyday life.

Definitions which include demanding and intellectual abilities as being part of scientific literacy but do not require a purpose for acquiring those abilities (e.g., Shamos' functional and true forms of scientific literacy; Shen's cultural scientific literacy; Arons' intellectual abilities), were thus placed in the learned category. Such interpretations appeared to be proposed only for the intellectual value of being

scientifically literate. On the other hand, when a context was suggested in which a scientifically literate individual needed to operate (e.g., Hirsch's 'oxygen of social intercourse'), or if a particular activity was required to be performed (e.g., reading science-related newspaper articles [Shamos; Hirsch; Hazen & Trefil] or solving practical problems [Shen]), then the concept was placed in the competent category. Competent relates in this instance to the extent of the ability to carry out such tasks.

Whereas Branscomb's (1981) professional science literacy fits in the learned category, the other proposed scientific literacies (e.g., universal science literacy, technological literacy, etc.) fit in the third category. The latter category was used if the suggested definition required the scientifically literate individual to play a particular role in society such as, for example, that of a consumer (e.g., Shen's practical scientific literacy) or citizen (e.g., Shen's civic scientific literacy). The kind of scientific literacy espoused by proponents of science for specific social purposes is also accommodated in the third category. Scientifically literate individuals in this interpretation of scientific literacy fulfil a particular role in society, namely that of citizens and consumers, and it is taken for granted that such citizens and consumers have a need for, and *use*, scientific knowledge in a wide variety of social contexts that affect their personal or economic well-being (e.g., nutrition, health, energy usage) (Jenkins, 1994). It is noteworthy that a "fundamental difference between medieval and modern approaches to literacy is that medieval assessments concentrate on cases of maximum ability, ... whereas modern assessors measure the diffusion of minimal skills among the masses" (Clanchy, 1979, p. 183). The different implied uses of literate in the various definitions of scientific literacy reflect this shift in emphasis.

In general, two features of the summary scheme of different definitions of scientific literacy can be identified. The first is related to the relative or absolute nature of the scientific literacy concept. The above three literate categories differ with respect to how the proposed body of knowledge to be mastered is defined. In the learned category, the required science content and intellectual abilities are defined with reference to the existing body of knowledge and way of thinking in the natural sciences (e.g., Snow, 1962; Arons, 1983), and is therefore defined in an absolute sense. The competent category is similarly defined in an absolute sense, as definitions of scientific literacy in this category (e.g., Hirsch, 1987; Hazen & Trefil, 1990) rely on a shared store of particular science content knowledge. In the function-in-society category, on the other hand, the required scientific literacy abilities are defined with reference to functioning effectively in society (e.g., Branscomb, 1981; Miller, 1983), that is, in a manner relative to society.

In order to further clarify the notion of scientific literacy, it is useful to elaborate briefly on the general relative-absolute distinction. At face value, an absolute definition of scientific literacy is perhaps appealing in that it implies a set of science content knowledge, skills, and attitudes toward science that would hopefully be common to all individuals. Although it is conceivable that such a set exists, it would be very difficult to identify, given the variety of social and economic systems that exist in the world. The notion of an absolute definition of scientific literacy is thus an impractical idea. To all intents and

purposes, scientific literacy depends on the context in which it is intended to operate, and “is inherently relative to the society in which it is used” (Miller, 1989b, p. 4). If it is accepted that scientific literacy is essentially a socially defined concept, it follows that the concept differs for different eras in time (e.g., pre- and post-nuclear age), geographical regions (e.g., heavy industry and agriculture based local economy), and communities or social conditions (e.g., suburban and informal or high-density housing). However, a major consideration that influences the definition of scientific literacy is the purpose of advocating this concept (see next section). If the attainment of scientific literacy for all is envisaged as a national goal, then this can only take place within an education system characterised by equality of opportunity (cf., Venezky, 1990). Therefore, only a single definition of scientific literacy is required.

The second feature of the summary scheme is the extent of involvement in and with society. Conceptions of scientific literacy in the learned category specify no involvement and appear to operate in a social vacuum, whereas definitions in the competent category require at least some form of interaction (e.g., the ability to communicate about scientific matters). (It is interesting to note that those authors who have proposed definitions of scientific literacy with a learned component that included ‘habits of mind’ generally do not specify to what use such habits should be put.) Definitions with respect to the third meaning of literate require the scientifically literate individual to use science in performing a function in society. The purpose for which scientific literacy is advocated is thus important, and the suggested reasons for promoting scientific literacy are discussed in the following section.

### **Why is scientific literacy important?**

There seems to be widespread agreement that scientific literacy is ‘a good thing’, yet there often exists only a tacit understanding of the reasons for advocating scientific literacy (Thomas & Durant, 1987). In this section, I restate a number of common arguments - based on Thomas and Durant (1987) and Shortland (1988) unless indicated otherwise - that have been suggested in favour of scientific literacy. The arguments for promoting scientific literacy can essentially be grouped into a macro and micro view, but the list is not meant to be exhaustive. The former relates to the alleged benefits that accrue to the nation, science, or society, whereas the latter relates to the enhancement to the lives of the individual. Each group of arguments is now described in turn.

#### ***Macro view***

The first common reason for advocating scientific literacy has to do with the connection between scientific literacy and the economic well-being of a nation. It is argued that national wealth depends on competing successfully in international markets. International competitiveness in turn relies inter alia upon a vigorous national research and development programme to, firstly, maintain or capture ground in

the world-wide race for new high-technology products in the case of developed countries, and secondly, to exploit smaller niche markets in the case of developing countries. Underpinning such a research and development programme is a steady supply of scientists, engineers, and technically trained personnel. Only nations whose citizens possess an appropriate level of scientific literacy will be able to sustain this supply. In addition to this argument, there is the view that scientific literacy will enable individuals to participate more intelligently in the productive sector of the economy (Walberg, 1983). Scientific literacy should therefore be seen as a form of human capital which influences the economic well-being of a nation in a number of different ways.

The second argument, allied to the economic perspectives, suggests that higher levels of scientific literacy among the populace translate into greater support for science itself. This would occur because a greater number of new recruits would be attracted to science, and because "it is often suggested that public support for science depends upon at least a minimal level of general knowledge about what scientists do" (Shortland, 1988, p. 307). Unless the general public values what scientists are attempting to achieve, science is unlikely to be financially supported from public funds. Hence Couderc (1971; cited in Shortland, 1988, p. 307) advocated knowledge itself as an " 'antidote to anti-science' ". A third way in which science itself may benefit from the promotion of greater scientific literacy is related to the public's expectations of science. The more the public understands about the objectives, processes, and capabilities of science, the less likely the public will be to acquire unrealistic and unrealisable expectations of science. While unrealistic expectations may lead to loss of confidence in, and eventually withdrawal of support for, science, increased levels of scientific literacy may counteract this potential disenchantment with science.

Related to public support for science is of course the public's right to influence the science policy-making process. The report of the Royal Society of London on *The Public Understanding of Science* states that a scientifically literate public would "... significantly improve the quality of public decision-making, *not* because the 'right' decisions would then be made, but because decisions made in the light of an adequate understanding of the issues are likely to be better than decisions made in the absence of such understanding" (Royal Society, 1985, p. 9). Citizens also have a legitimate interest in science, as a great deal of science is funded from public funds and as the products of scientific and technological research will inevitably have an influence on many aspects of public and private life (Thomas & Durant, 1987). Increased scientific literacy of citizens

may be thought to promote more democratic decision-making (by encouraging people to exercise their democratic rights), which may be regarded as good in and of itself; but in addition, it may be thought to promote more effective decision-making (by encouraging people to exercise their democratic right *wisely* [emphasis added]). (Thomas & Durant, 1987, pp. 5-6)

Prewitt (1983) supports this argument and makes a strong case for the fact that scientifically 'savvy' citizens help to underpin the democratic practice in societies with a scientific-technical base through meaningful involvement in and engagement with political processes, public policy-making, and social change.

The last argument operating at the level of relationships within society is concerned with the relationship between science and culture. Thomas and Durant (1987) assert that the general health of a nation in which science is practised depends on the effective integration of science in the wider culture. Science is generally seen by the public as the epitome of specialisation and technicality, and may therefore cut itself from the common cultural weal because of such a fragmentation process. The isolation of science from the wider culture may result in the general public failing to understand science properly, and as a consequence citizens respond to science with a mixture of adulation and fear. Increased scientific literacy of the public would thus counteract such a perceived 'cult' image of science.

The macro view of the arguments in favour of promoting scientific literacy thus includes benefits to national economies, science itself, science policy-making and democratic practices, as well as to society as a whole.

### *Micro view*

Turning to the direct benefits of scientific literacy to individuals, it has been suggested that improved understanding of science and technology is advantageous to anyone living in a science and technology dominated society (Thomas & Durant, 1987). More knowledgeable citizens, the argument goes, are able to negotiate their way more effectively through the society in which they live:

Personal decisions, for example about diet, smoking, vaccination, screening programmes or safety in the home and at work, should all be helped by some understanding of the underlying science. Greater familiarity with the nature and the findings of science will also help the individual to resist pseudo-scientific information. An uninformed public is very vulnerable to misleading ideas on, for example, diet or alternative medicine. (Royal Society, 1985, p. 10)

Widespread scientific literacy among the populace, the argument goes, would therefore result in citizens feeling more confident and competent to deal with science- and technology-related matters as they arise in the course of daily life.

Related to this very important area of benefits to individual citizens is the issue of employment. As economies are becoming more 'knowledge-based', the quality of human resources is increasingly seen as

the most important economic asset of modern science- and technology-based societies (Brooks, 1991). Scientifically literate individuals may therefore be in a favourable position to exploit new job opportunities and be able to take full advantage of technical developments in their place of work (Thomas & Durant, 1987).

The next set of arguments are closely related and are concerned with the intellectual, aesthetic and moral benefits of scientific literacy to individuals. It is commonly accepted that knowledge of science is an important element of what it means to be an educated person in the 20th century, and that "... science is an intellectual enabling and ennobling enterprise" (Shortland, 1988, p. 310). Snow (1962, p. 14) expressed this very poignantly when he wrote that "... the scientific edifice of the physical world ... in its intellectual depth, complexity and articulation, [is] the most beautiful and wonderful collective work of the mind of man". Promotion of scientific literacy therefore contributes to the promotion of the intellectual culture itself. Allied to the above argument is the aesthetic argument that suggests that "science is the distinctively creative activity of the modern mind" (Shortland, 1988, p. 310). Science has been eloquently described as "this century's cathedral building ... [and] this century's art" (Shortland, 1988, p. 310), and the aesthetic argument affirms that science is as central to a truly cultivated mind as literature, music, and the performing arts (Shortland, 1988). This argument therefore suggests that we should advocate scientific literacy for the "same sorts of reasons that we preserve beautiful buildings and paintings. Without knowledge of science, it is suggested, life would be that much less worth living" (Shortland, 1988, p. 310). Lastly, there is the ethical argument that suggests that "... the internal norms or values of science are so far above those of everyday life that their transfer into a wider culture would signal a major advance in human civilisation" (Shortland, 1988, p. 311). What is being suggested is that widespread scientific literacy would result in a better and more profound understanding of the norms and values of science, which "would make people not merely wiser but better" (Shortland, 1988, p. 311).

In summary, there are thus a number of reasons for promoting scientific literacy for both the common and the individual good. The above list of general arguments, however, may paint a somewhat overly neat and simplistic picture of a complex concept, for overlap between the various arguments can and does exist. For example, the interests of science and the effective integration of science in the wider culture are connected. Similarly, as Thomas and Durant (1987) have pointed out, the interests of individuals and those of national economies may overlap to a significant degree. The nature of such overlap is, in the opinion of Garrison and Lawwill (1992), problematic, and leads them to express strong reservations against making economic competitiveness *the* end of science education on moral grounds. The purpose for promoting scientific literacy is therefore not only dependent on the benefits envisaged to result from such literacy, but is also influenced by ideological and philosophical considerations (Champagne & Lovitts, 1989), such as for example, "differing visions of what kind of a society we are and what kind of society we aspire to be" (Kaestle, 1990, p. 66).



### Ways of measuring scientific literacy

Measures of scientific literacy are of course dependent on definitions of scientific literacy, as the concept cannot be effectively measured unless it is described in a sufficiently specific, bounded, and readily testable manner (Champagne & Lovitts, 1989; Shamos, 1989). Given the different interpretations of scientific literacy with respect to the concept's definition, nature, and purpose for promoting it (see above), it is not surprising that there exist also differences in the manner in which scientific literacy is measured. Earlier a distinction was made between the target groups and interests of at least three different groups involved in scientific literacy, namely those of (a) sociologists of science or science educators with a sociological approach to scientific literacy, (b) science educators; and (c) social scientists and public opinion researchers. Differences in the manner of measuring scientific literacy are evident from the methodologies used by these three interest groups.

Although the composite sense (i.e., multi-dimensional nature) of scientific literacy has been widely recognised (see the various definitions of scientific literacy described above), science education researchers have essentially not measured the concept in a composite manner (Chapter 3). Measures of individual dimensions (e.g., attitudes toward science, science content knowledge, the nature of science, etc.) were thus also used and referred to as measures of scientific literacy. The issues with respect to measuring scientific literacy in the science education context are, however, more extensively discussed in Chapter 3 (pp. 45-46) when the rationale for new scientific literacy test-items, as well as the format of the test-items developed in this study, is outlined. Therefore measures of scientific literacy used by science educators are not considered further here.

The sociological approach to investigating scientific literacy has been variously termed 'science for specific social purposes' (Layton et al., 1986), the 'context model' (Ziman, 1992), or the 'interactive model' (Layton et al., 1993). Within this measurement context it has been argued that it matters considerably whether the design of instruments is based upon whether individuals share the scientist's view of the natural world (i.e., the viewpoint of "insiders" [Ziman, 1984, p. 184]), or whether the instrument used to measure scientific literacy is based on what a citizen needs to know (i.e., the viewpoint of "outsiders" [Ziman, 1984, p. 184]) in order to cope effectively in a science- and technology-based society (Layton et al., 1986). As the purpose of the sociological approach to scientific literacy is to identify and describe the range of possible interactions between people's existing understandings of situations involving science and those understandings that emanate from science itself (Wynne, 1991), this approach necessarily employs contextual, small scale, and interpretative studies to describe the scientific literacy of adults. The main methods of obtaining data for this qualitative approach are case studies using participant observation, longitudinal panel interviews, structured in-depth interviews, and local questionnaires on specific issues (Wynne, 1991).

The approach taken by social scientists and public opinion researchers in measuring scientific literacy differs substantially from the above approach and has been termed the 'deficit model' by proponents of the sociological approach (Ziman, 1991). Social scientists are essentially interested in describing and comparing trends with respect to, for example, acquisition of specific science content knowledge, attitudes toward science, and support for science amongst a representative sample of a population (e.g., Miller, 1992; NSB, 1993). These researchers therefore use large-scale samples, standardised questions, and survey techniques to obtain their data. The work of Jon Miller has been particularly influential in this particular research framework (see Chapter 3).

Miller's (1983) paper proposing a particular multi-dimensional character for scientific literacy marked an important consolidation of this concept at the time (see above). Moreover, Miller's 'three constitutive dimensions' model of scientific literacy provided a sufficiently specific and bounded definition of scientific literacy in order for this concept to be measured in a composite manner. Although "the empirical study of the public understanding of science [in the United States] began with a 1957 national survey of Americans adults" (Miller, 1992, p. 23), the 1979 U.S. *Science & Engineering Indicators* survey, at Miller's suggestion, included for the first time items from all three dimensions of scientific literacy, and thus allowed the first construction of a measure of this concept (Miller, 1983, 1992). Measures of all three dimensions of scientific literacy have been included in all subsequent biennial surveys of this nature in the United States (Miller, 1987, 1992), and Miller's 'three constitutive dimensions model' of scientific literacy has formed the basis of almost all national and cross-national studies of the scientific literacy of adults conducted in the last decade or so (Chapter 3).

In summarising the results of a major programme of research into scientific literacy conducted in response to the report on *The Public Understanding of Science* (Royal Society, 1985), Ziman (1991) claimed that the deficit model, which attempts to interpret the knowledge of science held by individuals simply in terms of what they do *not* know, was not "an adequate analytical framework for many of the results of our research" (p. 101). Durant, Evans, and Thomas (1992) identified three principle objections to the deficit model. The critics claim that this model (a) "misrepresents science itself by portraying it as an unproblematic body of knowledge" (p. 162), (b) "overlooks the fact that a great deal of scientific knowledge is both remote from and largely irrelevant to everyday life" (p. 162), and (c) is either explicitly or implicitly normative, that is "the model embodies the specific value judgement that scientific understanding is inherently good" (p. 163) (Durant et al., 1992). In rebutting these claims, Durant et al. (1992) argue that while a great deal of scientific knowledge is problematic and contested, a great deal is also not. And while they concede that many individuals are ignorant about matters outside their immediate spheres of professional and personal interest, they argue that "this does not mean that it is either unrealistic or unwise to aspire to a level of universal education in which everybody possesses at least some elementary knowledge of a whole series of subjects..." (p. 163), including science (Durant et

al., 1992). Finally, they ask, is everybody with a low or bad score automatically branded as inferior? In citing from Gould (1981), they answer

Not at all. It is worth remembering that the French psychologist Alfred Binet developed the IQ test in order to identify those pupils who were most in need of educational assistance. Later, IQ scores were widely used to identify the specially gifted. To be sure, psychometry may be used to target resources in many different ways; but the example of Binet himself demonstrates that there is nothing necessarily prejudicial about the wish to find out how well individuals are doing in any particular areas of educational or scientific attainment. (Durant et al., 1992, p. 164)

But they concede that the deficit model is not suited to handling all aspects of the relationship between science and the public (Durant et al., 1992). This, then, is the essential point: approaches to measuring scientific literacy should be appropriate to the aims and objectives of the study. It is not simply a question of which approach is better or worse, but it is a question of which approach is more suited to uncovering what one wishes to find out! (In this respect, one is reminded of the general debate about the greater suitability of either quantitative or qualitative research methods in the social sciences.) A further point is that the context and deficit approaches to measuring scientific literacy have different limitations, and a choice of one or the other research framework represents a trade-off in information such as, for example, between the depth of understanding of science probed for in individuals and the coverage of the desired target population. Given a particular set of circumstances, it may be preferable to obtain one or the other kind of information. Other factors which need to be weighed up will almost certainly include research costs, available personnel, the time-frame of the study, and the breadth of science knowledge to be investigated.

## FEATURES OF THE APPROACH USED IN THIS STUDY

In the above section I have attempted to show that underlying the deceptively simple term scientific literacy are a number of different - often tacit - assumptions, interpretations, conceptions, and perspectives of what the term means, what introducing the concept should achieve, and how it is constituted. It is therefore not surprising that the concept of scientific literacy is often regarded as diffuse, ill-defined and difficult to measure (e.g., Champagne & Lovitts, 1989). If, however, positions with respect to scientific literacy are clearly spelt out, then arguments about this concept “‘may ... [not necessarily] be ... more fruitful or less heated, but they may be less frustrating’ ” (Ahlgren & Boyer,

1981, p. 174; cited in Champagne & Lovitts, 1989, p. 3). Below, I define scientific literacy as it is used here, and I describe the research framework employed in this study.

Scientific literacy is conceptually defined as a desired level of depth and breadth of scientific understanding appropriate to the interests and needs of the person being taught, set within the context of the developmental, educational, economic, and political needs and interests of a country at a given point in time (adapted from Champagne & Lovitts, 1989, p. 12). In Chapter 1 it was argued that scientific literacy of individuals in South Africa is required in order to achieve the necessary social upliftment of all South Africans. Given this requirement, the purpose of the present study is essentially two-fold. First, to attempt to assess the ability of the science education provided by the recent education system in South Africa to generate scientifically literate matriculants, and, second, to describe demographically determined trends of scientific literacy amongst this group (Chapter 1). Such data may be useful in the identification of individuals or groups who require or may benefit from intervention strategies and programmes designed to promote scientific literacy at the secondary/tertiary education interface (Chapter 4). These objectives represent a mixture of concerns corresponding to the *Leitmotiv* of researchers in two of the three interest groups associated with scientific literacy, namely those of the science education community and those of social scientists. Given the above objectives, Miller's research framework, based on large-scale samples and a survey technique, was deemed appropriate for the purpose of this study.

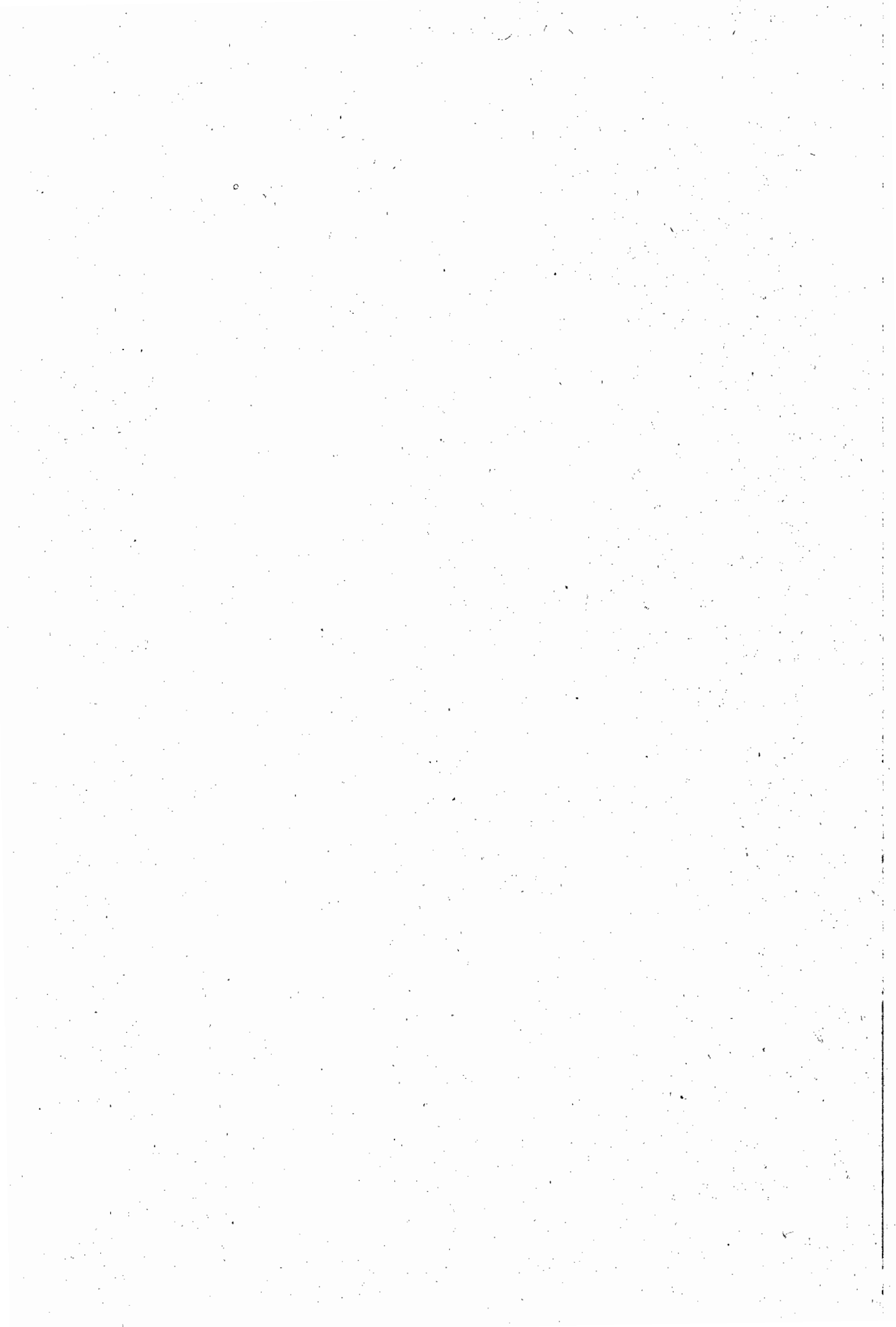
Miller's framework has been widely accepted (Chapter 3), and his 'three-constitutive dimensions' definition of scientific literacy (Miller, 1983), being more specific, is therefore more useful in constructing measures of scientific literacy, than other definitions. However, measures of scientific literacy should ideally be based on those principles of, and attitudes toward, science on which widespread consensus has been reached that these principles and attitudes form part of what it means to be scientifically literate. The American Association for the Advancement of Science overview report on literacy goals in science, mathematics, and technology, entitled *Science for all Americans*, represents such a consensus (AAAS, 1989). This report spells out the "knowledge, skills, and habits of mind associated with science, mathematics, and technology ... all Americans [should] have by the time they leave [high] school" (AAAS, 1989, p. 19). These recommendations are based

on the belief that the scientifically literate person is one who is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses scientific knowledge and scientific ways of thinking for individual and social purposes. (AAAS, 1989, p. 4)

Because *Science for all Americans* essentially represents the consensus view of the United States scientific community about the knowledge required in order to be regarded as scientifically literate

(Chapter 3), scientific knowledge can here be defined as that which is produced by, and carries the seal of approval of, this very large and successful component of the international scientific community (cf., Thomas & Durant, 1987). This sociological definition of science “presupposes nothing about the nature or the significance of science, other than that it is an authoritative or officially recognized form of knowledge” (Thomas & Durant, 1987, p. 2).

Although this AAAS literacy overview report *Science for all Americans* argues that scientific literacy is essentially required for economic reasons, it nevertheless also acknowledges the importance of personal reward as a consequence of being scientifically literate (AAAS, 1989; Chapter 3). In *Science for all Americans* the purpose for advocating scientific literacy is therefore very similar to the suggested reasons for advocating scientific literacy in South Africa (Chapter 1). The economic context of the United States (i.e., an industrialised, developed nation) and that of South Africa (i.e., a mixture of conditions pertaining to developed and developing nations) is very different. Yet the vision of what South Africa must achieve in order to improve the long-term quality of life of all South Africans is an essential component of the vision of what is required by Americans to maintain the continued well-being of their own nation: strong economic performance. The use of the AAAS scientific literacy recommendations as a basis for assessing the scientific literacy of South African matriculants is therefore believed to be justified. In the next chapter, the development of a pool of scientific literacy test-items based on selected AAAS literacy goals is described.





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## Chapter Three

### DEVELOPMENT OF A POOL OF SCIENTIFIC LITERACY TEST-ITEMS <sup>1</sup>

It is evident from the previous chapter, that scientific literacy has received much attention in the last decade. In the United States for example, much effort in science education reform has gone into achieving widespread scientific literacy, notably *Project 2061* sponsored by the American Association for the Advancement of Science (American Association for the Advancement of Science [AAAS], 1989), and *Scope, sequence and coordination* launched by the National Science Teachers Association (National Science Teachers Association, 1992). If we wish to be able to assess what progress we are making in promoting scientific literacy, whether at national, regional, or local level, we need to be able to measure this concept in a valid, reliable and preferably inexpensive manner.

I here describe the development of a pool of paper-and-pencil test-items of scientific literacy based on selected chapters of the 1989 AAAS overview report on literacy goals in science, mathematics and technology, entitled *Science for all Americans* (AAAS, 1989). This report spells out the knowledge, skills and attitudes that all students should possess as a consequence of their total school experience, in order to be regarded as scientifically literate.

#### APPROACH TO SCIENTIFIC LITERACY USED

In Chapter 2 it was argued that the problematic nature of scientific literacy as a concept arises principally out of the fact that definitions of scientific literacy depend markedly on the purpose for which the concept is advocated. The variety of arguments used to support scientific literacy (e.g., Shortland, 1988) allow for a variety of different interpretations of this notion, which in turn appear to give rise to a concept that is diffuse and ill-defined, and therefore difficult to measure (Champagne & Lovitts, 1989; Chapter 2). It is only since the publication of Miller's 1983 paper postulating a multi-dimensional character of scientific literacy that substantial progress has been made in measuring scientific literacy in a widely applicable, and reasonably comparable, way in large-scale surveys. Miller (1983) suggested that the concept of scientific literacy consists of three dimensions: an understanding of the norms and methods

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1. This chapter has been published in a recent issue of *Science Education* (see Laugksch & Spargo, 1996).



of science (i.e., the nature of science); of key scientific terms and concepts, and an awareness and understanding of the impact of science and technology on society.

However, as mentioned Chapter 2, other authors extend the scope of attributes characterising scientifically literate individuals to include intellectual abilities or 'habits of mind'. For example, Arons (1983) contends that individuals should be able to recognise "when questions such as 'How do we know...? Why do we believe...? What is the evidence for...?' have been addressed, answered, and understood, and when something is being taken on faith" (Arons, 1983, p. 93). In addition, scientifically literate individuals should be able to correctly apply scientific knowledge and reasoning skills to solving problems and to making decisions in their personal, civic, and professional spheres (e.g., Brickhouse, Ebert-May, & Wier, 1989; Laetsch, 1987).

These additional elements of scientific literacy are included in the model of scientific literacy recommended by *Science for all Americans* (SFAA). This model is not only based on knowledge of science, technology, and mathematics, but also includes values, attitudes and thinking skills - "habits of mind" - associated with those disciplines (AAAS, 1989). In the view of SFAA, scientific literacy further encompasses knowledge of applications of science (e.g., in areas of agriculture, manufacturing, energy sources and uses, etc.); historical perspectives of significant discoveries during Western cultural development (e.g., splitting of the atom, explaining the diversity of life, harnessing power, etc.); themes common to science, mathematics, and technology (e.g., the notion of systems, models, pattern of change); as well as sociological perspectives of human society (AAAS, 1989). Moreover, in the SFAA model the scientifically literate individual "uses scientific knowledge and scientific ways of thinking for individual and social purposes" (AAAS, 1989, p. 4).

Miller (1989) makes a strong case for the necessity and desirability of scientific literacy largely, but not exclusively, on the grounds that individuals require the skills and knowledge encompassed by the notion of scientific literacy in order to function effectively as citizens and consumers in today's society. Almost all of the additional attributes included by SFAA in its model of scientific literacy would appear to contribute substantially to achieving this goal and, in my view, the great majority of these attributes do not comprise a further dimension of scientific literacy but rather form part of the original three proposed by Miller (1983). They overlap the dimensions of the nature of science, science content knowledge, and the impact of science and technology on society, blurring the boundaries between these dimensions in this process. The additional attributes represent a 'deeper', more profound, level of understanding of what it means to have a working knowledge of science in today's scientifically and technologically orientated world than the understanding originally encompassed by Miller's three dimensions.

## RATIONALE FOR NEW TEST-ITEMS

Much work has been carried out in ascertaining separately students' views and knowledge in each of the three dimensions of scientific literacy but I wish to make reference here to only a small number of important overviews of these research foci. The nature of science and the impact of science and technology on society will be discussed concurrently as they form a connected theme. As may be expected, Miller's second dimension of scientific literacy, that of science content knowledge, has been of particularly keen interest to science educators, as the assessment of students' conceptions of various important concepts in science is vital to much of teaching and learning in the sciences. Particularly in the identification and assessment of misconceptions or alternative frameworks, the research literature is now considerable (see, for example, Anon, 1989; Carmichael, Driver, Holding, Twigger, & Watts, 1990; Pfundt & Duit, 1990). Individuals' conceptions of the nature of science, Miller's first dimension of scientific literacy, has been comprehensively reviewed by Lederman (1992) and Meichtry (1993). Assessment of students' perceptions in this area did not commence until the 1950s, but since then a large body of literature has been established in this field (Lederman, 1992). A number of instruments have been developed to investigate particular aspects of students' understanding of the nature of science (Lederman, 1992; Meichtry, 1993), of which the most widely known are probably Cooley and Klopfer's (1961) Test on Understanding Science (TOUS), Kimball's (1967/68) Nature of Science Scale (NOSS), and Rubba and Anderson's (1978) Nature of Scientific Knowledge Scale (NSSK). All three tests employed a large number of test-items either based on surveys of the then current literature both in science and the history and philosophy of science (e.g., TOUS and NOSS), or on the early works on scientific literacy (e.g., NSSK) (Cooley & Klopfer, 1961; Kimball, 1967/68; Rubba & Anderson, 1978).

The nature of science is associated with Miller's third dimension of scientific literacy (i.e., the impact of science and technology on society) through content such as, for example, the epistemology of science and its social context (Aikenhead & Ryan, 1992). This third dimension is closely allied to the Science-Technology-Society (STS) movement, which emphasises a holistic, problem-solving approach to science teaching and attempts to deal with current social and technological issues impacting on society (Yager, 1993). In this research field, Aikenhead and Ryan (1992) have developed a sophisticated instrument, Views on Science-Technology-Society (VOSTS), that monitors students' views on a broad range of STS topics: science and technology, the reciprocal influence of science on society and technology, the influence of school science on society, characteristics of scientists, social construction of scientific knowledge and technology, and the nature of scientific knowledge. In general, these topics are very similar to the content covered by some of the scientific literacy test-items in the item pool (see below). However, a fundamental difference between VOSTS items and the scientific literacy test-items is that the

former “focus on the reasons that students give to justify an opinion” (Aikenhead & Ryan, 1992, p. 480), whereas the items developed here test for factual information, comprehension of concepts, and for particular attitudes toward science that the AAAS has recommended every high-school leaver should possess in order to be regarded as scientifically literate. Moreover, VOSTS items are limited to the nature of science and STS topics, whereas the majority of the scientific literacy test-items cover key concepts in science.

Thus, despite the considerable body of research focusing on separate assessment of the dimensions of scientific literacy, few *composite* measures of all three have, to the best of my knowledge, been developed and published in the last decade. Such simultaneous assessments of all three dimensions of scientific literacy are more efficient than separate, individual assessments of the dimensions, and are therefore more suited for inexpensive and easy administration to hundreds or thousands of respondents normally associated with large-scale surveys. With the exception of Lord and Rauscher (1991), who based their short scientific literacy questionnaire on information contained in upper primary and middle school life science textbooks, and Cannon and Jinks (1992), who used a ‘cultural literacy’ approach (see Hirsch, 1987) to assessing scientific literacy, Miller’s framework has formed the basis of almost all recent surveys of scientific literacy. Such studies have been carried out in the United States since 1979 as part of the biennial Science & Engineering Indicators series (Miller, 1987, 1992), in Britain (Durant et al., 1989, 1992), in the European Community (INRA [Europe] & Report International, 1993), in China (Zhang & Zhang, 1993; Ge, Liu, & Li, 1995), in Canada (Einsiedel, 1991, 1994), in Japan (Office of the Prime Minister of Japan, Public Relations Office, 1991, cited in NSB, 1991), in Sweden (Fjæstad, 1994), in South Korea (Kim, 1995), and in Australia (Bureau of Industry Economics [BIE], 1995).

In his research methodology Miller and his collaborators employed different ways of measuring the three dimensions of scientific literacy, the measures being modified from time to time (Miller, 1992). Understanding of the scientific approach was usually assessed by the question “Please tell me, in your own words, what does it mean to study something scientifically?” (Miller, 1993). In the latest studies (e.g., INRA [Europe] & Report International, 1993; NSB, 1993), this question has been replaced by questions describing different aspects of scientific methods, namely, the experimental method, the concept of a control group, and probability. Measures of the second dimension, that of an understanding of key scientific terms and concepts, have since 1988 been based on 11-13 quiz-type items concerning knowledge of more recent scientific discoveries. These items are based on the 20-item Oxford Scientific Knowledge Scale of Durant et al. (1989). Measures of the third dimension of scientific literacy appear to have undergone the most change since Miller’s initial efforts. From questions about the potential benefits or dangers of chemical additives in food, nuclear power, and space exploration (Miller, 1983), measures of an awareness of the impact of science and technology on society now consist, amongst other things, of questions on (a) the perceived importance of science and technology in general and practical terms;

(b) the frequency with which individuals tend to keep up with the televised, broadcast and printed news; and (c) individuals' stated interest in a range of news themes (e.g., sports, politics, medical discoveries, new inventions, etc.). For details of these questions see INRA (Europe) and Report International (1993), and NSB (1993).

Miller's framework has been widely accepted, and, as mentioned earlier, has formed the basis of many national and cross-national studies. Moreover, the studies based on Miller's framework have been immensely useful and undoubtedly provided new insights into the level of the public's understanding of science. Nevertheless, Miller's methodology has a number of limitations. Firstly, with the exception of the impact-of-science-and-technology-on-society dimension, measures of the other dimensions of scientific literacy have been based on a relatively small number of items with unspecified content validity. Measures of scientific literacy should ideally be based on items testing comprehension and awareness of important principles in, and attitudes toward, science on which there is widespread, documented agreement that these principles and attitudes form part of what it means to be scientifically literate. Secondly, surveys of scientific literacy based on Miller's methodology employed face-to-face or telephone interviews (NSB, 1989, 1991) which are expensive and time-consuming to carry out. This restricts their general, more widespread, use for less ambitious or well-funded projects which may have only a small number of personnel available. I have taken a different, but essentially complementary, approach to Miller's in developing items which could be used in measuring scientific literacy. I have developed a large pool of test-items, used a structured response item format, and, most importantly, based the content of the scientific literacy test-items on *Science for all Americans*. These test-items are designed to be a refinement of previous attempts to measure scientific literacy along its three dimensions in a composite manner.

## ASSESSMENT STRATEGY

In order for future users of the scientific literacy test-items to be able to interpret responses to the test-items not only in terms of competencies on any of Miller's three dimensions of scientific literacy but also in terms of cognitive knowledge in particular content areas, the items were constructed and validated as criterion-referenced test-items (see Nitko, 1984).

### Purpose of test-items

Doran, Lawrenz, and Helgeson (1994) consider six groups to be useful in targeting assessment devices appropriately, namely, students and parents, teachers and instruction, districts and programs, states,

national and international levels. These groups can be crossed by three levels of timing of assessment, namely, “beginning (i.e., diagnostic or baseline), middle (i.e., formative or process), and end (i.e., summative or outcome)” (Doran et al., 1994, p. 394). The scientific literacy test-items are targeted at the level of baseline and outcome studies, that is, at either end of the timing spectrum. I believe that the test-items will be useful in monitoring the scientific literacy status of the middle to upper levels of information aggregation in this matrix (i.e., at the local, regional, national and international level), in a simple and comparatively inexpensive manner. In general, the purpose of the scientific literacy test-items is thus to be able to contribute to the monitoring of progress towards regional or national goals in science education, and in this manner to be able to reflect on excellence and accountability in education (e.g., Champagne & Newell, 1992).

More specifically, the scientific literacy of students is assessed in comparison to a particular, predetermined, model of scientific literacy: that of the AAAS. The purpose of the test-items is to test for comprehension of the facts and concepts that the AAAS consider to be an integral part of scientific literacy; that is, the items attempt to assess the extent, quality, and structure of the information base the AAAS recommends all high-school leavers should possess in order to be regarded as scientifically literate. The test-items also assess whether high-school leavers possess particular beliefs with regard to the nature of science and the interaction between science, technology and society - beliefs that the AAAS has identified as forming part of scientific literacy. The item pool is thus testing only certain aspects of scientific literacy, as knowledge of interdisciplinary concepts, applications of science, and the ability to apply knowledge for decision-making and problem-solving is not being tested with these items. Nevertheless, the extent of the information base is a vital component of scientific literacy (Champagne & Newell, 1992), as it forms the foundation for all further attributes of scientific literacy. In my view, comparatively little informed decision-making and problem-solving can take place in the absence of knowledge of relevant facts and concepts. Linn, Clement, Pulos, and Sullivan (1989), for example, suggest on the basis of their research that the importance of science topic knowledge in reasoning should not be underestimated. As Walberg (1983, p. 5) has put it, “... without ... basic knowledge, or literacy, ... [students] cannot be expected to go on to the higher reaches of thought.” Moreover, knowledge of factual information would seem to be essential for making sense of interdisciplinary concepts and applications of science. Thus, despite the fact that test-items of this nature are accepted to have limitations, I am confident that the test-item pool developed here is an important step in assessing scientific literacy.

### **Item format**

In keeping with the stated aims of the scientific literacy test-items (see above), I have chosen to attempt a very broad coverage of Miller’s three dimensions of scientific literacy. In the numerous and varied

contexts of different regional, national and cross-national assessments and comparisons of scientific literacy, I strongly believe that the results of studies employing a broad approach are both useful and illuminating. This approach I believe to be particularly appropriate for the South African context where levels of scientific literacy have yet to be investigated in a large-scale, systematic manner (Chapter 1). Further, subsequent in-depth studies employing possibly different item formats could then investigate more extensively the trends encountered in such earlier studies.

In order to achieve the desired content coverage in the invariably limited time available for testing, a true-false item format was chosen for the test-items. True-false items are efficient and relatively easy to write, but they are of course not above criticism. The most frequent indictments of this item format are charges that items are subject to error due to guessing, that items are often ambiguous, that items reward memorisation, and that items have a harmful effect on learning (Ebel & Frisbie, 1991). However, it has also been noted that there have been few careful empirical investigations of these charges (Ebel & Frisbie, 1991). Guessing of correct answers can be substantially reduced by the addition of a "Don't know" option in survey questionnaires (Ebel & Frisbie, 1991) and later users of the scientific literacy test-items (and users of the *Test of Basic Scientific Literacy* [Chapter 4]) should be strongly encouraged to make use of this option. The second objection has been attempted to overcome by attempting to adhere to specific test-item writing guide-lines and by using a panel of acknowledged experts to evaluate the technical quality of the test-items. These strategies are further detailed below in the sections on item development and item validity.

The third and fourth charges are related to the nature of assessment, as public interest in the United States during the 1980s and 1990s has increasingly focused on assessment of educational outcomes, particularly in science and mathematics education (Doran et al., 1994). The charges are thus part of the current policy debates on assessment reform in general (see, for example, the special issue of *Harvard Educational Review* [Vol. 64(1), Spring 1994] on assessment and educational equity), and in science education in particular (see, for example, the special issue of the *International Journal of Educational Research* [Shavelson, 1994] on performance assessment). The powerful influence of assessment on administrators, teachers, pedagogies and curriculum development is now widely recognised (Reardon, Scott, & Verre, 1994; *Alternative Assessment and Technology*, 1992, cited by Doran et al., 1994), and hence there is a concern that traditional assessment devices, when used for decision-making, encourage instruction that tends to emphasise decontextualised, rote-oriented tasks (Darling-Hammond, 1994). Coupled to this are changes in our understanding about how students learn as well as growing evidence of the limitations of traditional assessment instruments in measuring that learning (Baxter & Shavelson, 1994; Darling-Hammond, 1994). Thus "efforts to raise standards of learning and performance must rest in part on strategies to transform assessment practices" (Darling-Hammond, 1994, p. 6), and hence the call for different assessment strategies.

Being fully aware of the need for alternative performance assessment methods (e.g., open-ended, hands-on investigations) specifically in science education (e.g., Champagne & Newell, 1992; Doran et al., 1994; Shavelson, 1994), I realise that it is currently unfashionable to advocate the use of traditional instruments such as paper-and-pencil tests with a true-false item format. However, assessment strategies and item formats should fit the purpose for which the assessment instruments are being designed. As was indicated earlier, the scientific literacy test-items do not test complex cognitive abilities, nor is it suggested that the test-items should be used for standardised, national competency-based certification purposes or other similar important decisions involving individuals. Given the purpose for which the scientific literacy test-items have been developed, and given what the test-items are intended to test for, it is averred that the assessment strategy and item format selected here are appropriate and that they will yield useful results in many varied and important contexts.

## THE TEXT

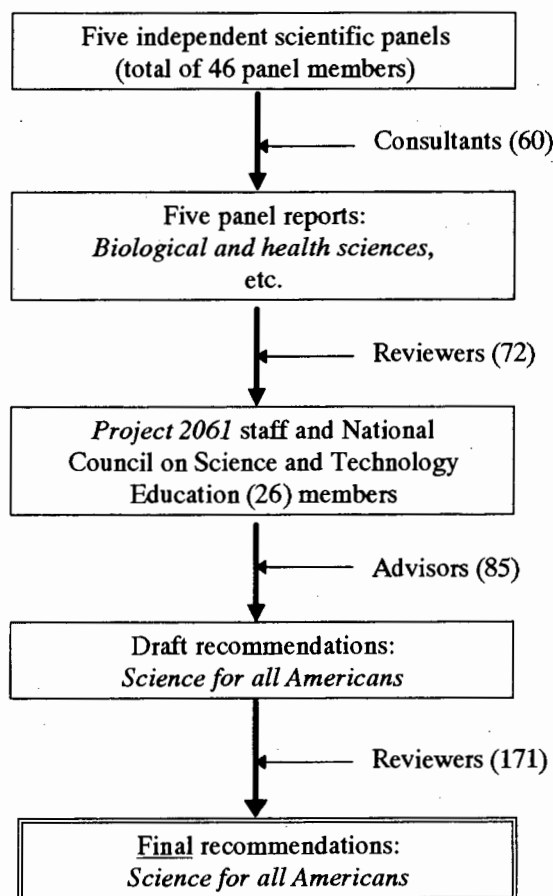
### *Science for all Americans (SFAA)*

*Project 2061* is a long-term, three-phase undertaking of the AAAS designed to contribute to the reform of education in science, mathematics, and technology in the United States (AAAS, 1989). Phase I of this endeavor was completed with the publication of SFAA. *Science for all Americans*

consists of a set of recommendations by the National Council on Science and Technology Education [NCSTE] - a distinguished group of scientists and educators appointed by the American Association for the Advancement of Science - on what understandings and habits of mind are essential for all citizens in a scientifically literate society. (AAAS, 1989, p. 3)

The process followed and the categories of participants involved in the preparation of this report are outlined in Figure 3.1. In arriving at the recommendations contained in *Science for all Americans*, NCSTE members in consultation with the AAAS *Project 2061* staff drew on the report of each of the five independent scientific panels (AAAS, 1989) in the biological and health sciences (Clark, 1989), on mathematics (Blackwell & Henkin, 1989), in the physical and information sciences and engineering (Bugliarello, 1989), in the social and behavioral sciences (Appley & Maher, 1989), and on technology (Johnson, 1989). The draft recommendations were submitted to reviewers before the final recommendations were reached (Figure 3.1). The content of SFAA was thus arrived at in a careful,

systematic and thorough manner, and represents the final recommendations of the NCSTE on what it means to be scientifically literate.



**Figure 3.1.** A diagram of the process followed, and categories of participants involved, in writing *Science for all Americans* - Phase I of Project 2061. The number of participants involved at each stage is given in parentheses. Details were derived from the text and Appendix A of AAAS (1989).

### Ideological framework of SFAA

Definitions and interpretations of scientific literacy are invariably dependent on what arguments are being used to support and promote the notion of scientific literacy (Jenkins, 1990, 1992; Chapter 2). This means that different definitions and conceptions of scientific literacy may contain different, generally implicit, ideas about science, society and how a scientifically literate person should function in society



(Champagne & Lovitts, 1989). "The fact that the assumptions about the context are neither stated nor negotiable is a source of frustration in efforts to reconcile differences in descriptions of scientific literacy" (Champagne & Lovitts, 1989, p. 4). To overcome this limitation, and for readers to be able to place the concept of scientific literacy as it is used here into proper context (cf. Chapter 2), it is necessary and important to state the ideological framework within which SFAA is located. The following description is based on Fourez (1989), to my knowledge the only published attempt to analyze how related portrayals of science, technology, society, and history are presented in SFAA.

For Fourez, two arguments for promoting scientific literacy dominate SFAA. One is centred on personal self-fulfillment, that is, to prepare individuals to lead, amongst other things, personally fulfilling and responsible lives. The other argument is based on the belief that America's future depends on the quality of science education received by individuals, that is, the argument is based on national socio-economic needs. In Fourez' view, however, SFAA does not provide any necessary analysis of the interaction between these orientations.

For Fourez, SFAA represents a philosophy of science that is objectivist and empiricist. "Observation is presented mainly as a passive process of trying to see what happens, even when scientists actively probe the world and control the conditions of observation" (Fourez, 1989, p. 95). The scientific enterprise is also represented as non-authoritarian, with nothing being "said about the criteria by which it is decided what questions are more important or who decides what is important" (Fourez, 1989, p. 95). Furthermore, the portrayal of science in SFAA expresses in many respects a technocratic point of view. "Science is based on neutral observation of a well-organised, lawful universe and science gives the results that can be applied in utilitarian ways. For the most part, the influence of society on science remains external" (Fourez, 1989, p. 96).

For Fourez, the technocratic orientation of SFAA is also evident in the section on technology: scientific practice is presented as neutral while technology is presented as value laden (Fourez, 1989). SFAA portrays technological creativity as always implying a compromise between conflicting points of view, the task being " '...to arrive at a design that reasonably balances the many trade-offs (AAAS, 1989, p. 41)' " (Fourez, 1989, p. 98). But the important question about whose reason or whose criteria will be predominant, is not addressed by SFAA (Fourez, 1989). Moreover,

it is assumed implicitly in *Science for All Americans* that technology can be conceptualized adequately as a tool that can be used or not used. There is no hint of the ways in which organization and social dynamics are constituent parts of technology. (Fourez, 1989, p. 99)

With respect to the individual's role in participating in public debates, for Fourez SFAA reflects the dominant ideology of an individualistic society. "What matters is the *cumulative effect of individual decisions* rather than *politically organized groups of citizens*. The image of society conveyed is of an aggregate of separate individuals, rather than organised associations" (Fourez, 1989, p. 100).

For Fourez, the epistemology of SFAA "suggests that science observes and describes the world *as it is*" (Fourez, 1989, p. 104). Thus, the history of science portrayed by SFAA is the story of the results and the triumph of science (Fourez, 1989), while "the economic, political, and military factors of scientific development are essentially neglected" (Fourez, 1989, p. 104). This is, however, not the case where the history of technology is concerned, as economics is emphasised here by SFAA (Fourez, 1989).

## DEVELOPMENT OF TEST-ITEMS

In the development of the scientific literacy test-items I have built on earlier work by Miller and his colleagues. Separate pools of test-items were developed for each of Miller's (1983) 'three constitutive dimensions' of scientific literacy, namely, the nature of science, science content knowledge, and the impact of science and technology on society. As mentioned above, these test-items are designed to be a refinement of previous attempts to measure scientific literacy along the three dimensions in a combined manner.

### Item generation

As described above, generation of the test-items was based on the AAAS overview report on literacy goals in science, mathematics and technology, entitled *Science for all Americans* (AAAS, 1989). The AAAS recommendations consist of 12 chapters of varying length, addressing different knowledge, skills and attitudes in a variety of different domains. In accordance with Miller's multi-dimensional model, the following chapters were used in constructing the item pools for the different dimensions of scientific literacy. For the nature of science dimension, *The Nature of Science* (chap. 1) was used, focusing on the "scientific world view, scientific methods of enquiry, and the nature of the scientific enterprise" (AAAS 1989, p. 25). For the science content knowledge dimension *The Physical Environment* (chap. 4), *The Living Environment* (chap. 5) and *The Human Organism* (chap. 6) were used. Chapter 4 focuses on the "structure of the universe and the major processes that have shaped the planet earth, and the concepts with which science describes the physical world in general-- ... matter, energy, motion and forces" (AAAS, 1989, p. 47). Chapter 5 focuses on the

diversity of life as reflected in the biological characteristics of the earth's organisms; the transfer of heritable characteristics from one generation to the next; the structure and functioning of cells ...; the interdependence of all organisms and their environment; the flow of matter and energy through the grand-scale cycles of life; and how biological evolution explains the similarity and diversity of life. (AAAS, 1989, p. 59)

Chapter 6, the last chapter used for the science content knowledge dimension, focuses on "human identity, the human life cycle, the basic functions of the body, learning, physical health, and mental health" (AAAS, 1989, p. 67). For the impact of science and technology on society dimension *The Nature of Technology* was used, focusing on the "connection between science and technology, the principles of technology itself, and the connection between technology and society" (AAAS, 1989, p. 38).

In line with procedures suggested by Roid and Haladyna (1982) for transforming prose into test-items, I went to great lengths to ensure in the generation of the scientific literacy test-item pool that only the most important ideas in the given text were tested. Key sentences containing what were believed to be important ideas in, and attitudes toward, science were chosen after careful reflection for each paragraph of the relevant chapters of the AAAS document. The fact that the AAAS recommendations had been deliberately formulated in a very clear and structured way (AAAS, 1989, p. 22) made this task more valid and also considerably easier. Two or three key sentences were sometimes joined by me to form one statement or, less frequently, summarised. Only occasionally were important ideas abstracted from the paragraphs, and only in extremely rare instances could no important idea or overriding theme be identified per paragraph.

The key sentences and statements chosen were validated in an operationally defined manner by acknowledged content experts as containing the key idea(s) expressed in the SFAA paragraphs. The validation instructions were trialed on eleven academic staff members of two tertiary educational institutions and the final instructions were revised and modified in the light of the comments and responses received. Seventy-seven randomly chosen Fellows of the Royal Society of South Africa, the premier scientific society in South Africa, in appropriate scientific disciplines were requested to read their allocated chapter, and to identify in each paragraph what they believed were key sentences containing important ideas in, or attitudes toward, science (Appendix A, pp. 203-206). In the light of their own choices, Fellows were asked to accept or modify the sentence selected by me, or to substitute it with a sentence of their choice.<sup>2</sup> Each Fellow validated the sentences of only one chapter which fell within his or her area of acknowledged expertise. Sentences in the chapter on the nature of science were validated by Fellows in any of the various scientific disciplines: personal experience leads me to believe

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2. Fellows were also requested to assign importance ratings to the selected key sentences and ideas. These ratings were then used in the selection of test-items for the final form of the scientific literacy test (see Chapter 4, p. 69).

that the great majority of these distinguished scientists have deliberated carefully upon the nature of science during their career, and thus would have some worthwhile insights in this area. The overall response rate was 52%. Between six and eight Fellows validated the sentences of any one chapter.

After comprehensive revision, a pool of 240 statements containing key ideas in, and attitudes toward, science was compiled. These statements formed item stems which were transformed into matched true-false test-items. In doing this, it was endeavoured to develop items that were expressed as simply, concisely and clearly as possible. Great care was taken in this process. Firstly, various widely accepted guidelines for writing effective true-false test-items, such as those supplied by Ebel and Frisbie (1991, pp. 143-148) were adhered to: (a) items should test the respondent's knowledge of an important idea; (b) answering items correctly should require understanding as well as memory, that is, testing recall of meaningless words learned by rote should be avoided; (c) the correct answer to items should be defensible; (d) the correct answer to items should not be obvious to anyone, that is, items should test special knowledge; and (e) items should not include an artificial, tricky negative. Furthermore, it was ensured that only one key idea or attitude was reflected per item. As a result, many validated statements had to be split into a number of separate items. Trivial propositions and double negatives were avoided. However, in the development of the false version of some test-items it was occasionally found difficult to avoid inserting a "not" in the true version because of the items' often greatly limited context. In rare instances a meaningful false version could not be constructed.

Secondly, it was attempted to ensure that each item was meaningful to the respondent. This was a particularly important step as I strove to ensure that the respondent could understand the context and content of the item as much as possible within his or her own life experiences. Fewer abstractions than in the original statements were consistently used, and it was endeavoured to concretise items with examples wherever appropriate and feasible. However, care was taken not to lead the respondent or to give clues to the answer. Wherever appropriate, it was attempted to eliminate the condition-laden, ultra cautious writing common in science, as sentences expressing key ideas in a typically cautious and hedged manner were often unnecessarily complex and, because of their fine nuances, difficult to understand. In my view, this made the items more positive and powerful, and thus for the respondents easier to understand and to evaluate, as well as being shorter to read. Validated statements were sometimes taken out of the context addressed in the general paragraph and this tended to distort the resulting item and made the item meaningless. Items developed from such statements were expanded within the original framework of the paragraph to reintroduce the relevant context.

The content of some validated key sentences was directly related to ideas or facts stated in sentences that preceded them. Normally, items developed from such key sentences become technically defective as respondents have to understand and agree with the preceding idea or concept before being able to respond to the actual test-item, that is, two ideas are being tested in the same item. To overcome this problem, it

was elected to precede each version of such a test-item with an appropriate true, or 'given', fact selected from the relevant text in the paragraph. Respondents would thus be making a decision regarding the truth of statements contained in such test-items in relation to the given fact, this fact being clearly identified.

Thirdly, as it is possible that the test-items developed here may well be used in a wider international context, and as in many parts of the English-speaking world there are sizeable minorities who do not have English as a home language, it was attempted to develop test-items with vocabulary and syntax appropriate for English second language speakers (see, for example, Bird & Welford, 1995; Rutherford, 1993; Rutherford & Nkopodi, 1990) through strategies outlined below. Moreover, the original AAAS recommendations were "written for today's educated adults, not students" (AAAS, 1989, p. 23), and it has been shown that students in general not only have difficulty understanding the meaning of many scientific terms, but also have difficulty understanding words which are used in explaining science concepts (e.g., Ryan, 1985ab). I was thus also sensitive to the effect of language on student performance in general, particularly pertinent in the case of structured response test-items (e.g., Johnstone & Cassels, 1978; Cassels & Johnstone, 1984). Unnecessary scientific jargon was eliminated as far as possible from the items, and potentially difficult scientific and non-scientific vocabulary was attempted to be clarified through the frequent use of "i.e.". Complicated and intricate sentence structure were avoided and it was attempted to develop items that read 'smoothly', requiring ideally only one reading. Visual pointers such as underlining and italics were used to ensure that the intended emphases was also perceived as such by the respondents. All the above considerations were incorporated into the item-writing procedure to minimise possible unintentional ambiguities of test-items.

Through a series of carefully structured and sequenced steps I have developed a pool of 472 true-false test-items of scientific literacy, testing for comprehension of 240 key ideas in, and attitudes toward, science. The test-item pool for each of the three constitutive dimensions of scientific literacy, namely, the nature of science, science content knowledge, and the impact of science and technology on society, consists of 83, 325, and 64 items, respectively. The earth sciences, the physical/chemical sciences, and the life and health sciences each contributed 43, 31, and 91 key ideas to the pool. These broad content areas were covered by 85, 59, and 181 test-items, respectively.

## Validity

A key and very significant attribute of any rigorous test instrument is the requirement that the instrument actually measures what it was intended to measure, that is, that the instrument contains items that are valid. This is a constant, major concern, not least because an instrument's reliability is very much influenced by its validity. However, validity should be established for each particular use of a test (Shepard, 1993). As an item pool is being designed here, and not a specific, contextualised test

instrument for a narrowly defined target population, validity cannot here be evaluated in full (but see Chapter 4, pp. 71-81). Nevertheless, forms of validity that are relevant to the development of the test-items in general are content, construct and item validity.

### *Content validity*

Content validity focuses upon the extent to which the content of an indicator corresponds to the content of the theoretical concept it is designed to measure (Zeller, 1994). In the case of SFAA, 460 scientific panel and NCSTE members, consultants, reviewers and advisors (Figure 3.1) were involved in the various stages of establishing the final recommendations which spell out the knowledge, skills, and attitudes all school leavers should possess in order to be regarded as scientifically literate. This total is slightly inflated as not all reviewers, consultants and advisors were mutually exclusive (see Appendix A of AAAS, 1989). Nevertheless, it is clear that the AAAS overview report *Science for all Americans* resulted in hundreds of scientists, engineers, mathematicians, historians and educators being involved in various capacities in establishing explicit scientific literacy goals (AAAS, 1989). This report is thus based on a substantial degree of consensus in the American scientific community on what it means to be scientifically literate (AAAS, 1989; Ahlgren & Rutherford, 1993). It is therefore averred that the recommendations contained in *Science for all Americans*, and hence the test-items based on these recommendations, possess a significant degree of content validity. The test-item pool is, however, not based on the complete 'content universe' of the SFAA model of scientific literacy, as only selected, and not all, chapters of SFAA were used as the content basis for the items. Ideas and concepts related to mathematics and the mathematical world, the "major human activities that have shaped our environment and our lives" (AAAS, 1989, p. 89), "significant discoveries and changes that exemplify the evolution and impact of scientific knowledge" (AAAS, 1989, p. 111), common themes that pervade science, mathematics and technology (AAAS, 1989), and "habits of mind" (AAAS, 1989, p. 133) that according to SFAA are part of what it means to be scientifically literate, are not covered by the test-item pool.

### *Construct validity*

This type of validity "focuses on the assessment of whether a particular measure relates to other measures consistent with a theoretically anticipated way" (Zeller, 1994, p. 6572). Independent corroboration of the validity of the specific key ideas in science tested for in the test-items is evident from *Benchmarks for science literacy* (AAAS, 1993). This publication is the product of Phase II of *Project 2061*, and reformulates the goals for scientific literacy of each SFAA chapter into intermediate levels of understanding for grade spans K-2, 3-5, 6-8, and 9-12 (AAAS, 1993; Ahlgren & Rutherford, 1993),

corresponding approximately to ages 5-7, 8-10, 11-13, and 14-17, respectively. This process was underpinned by research on students' understanding and learning in the sciences, and is described more fully in AAAS (1993) and also by Ahlgren (1993). The draft version of *Benchmarks* underwent a nationwide review in the United States, and over 1300 responses were received from "... school teachers, administrators, scientists, mathematicians, engineers, historians, and experts on learning and curriculum design" (AAAS, 1993, p. XII). Other reviewers included scientific and educational organizations (AAAS, 1993).

*Benchmarks* had not yet been published when the pool of scientific literacy test-items was developed. Nevertheless, 140 (58%) of the 240 key ideas in, and attitudes toward, science covered in the pool are contained in *Benchmarks* as explicit benchmark statements. These statements are specified thresholds that describe the level of understanding expected to be reached at certain school levels by all students on their way to becoming scientifically literate (AAAS, 1993). Of those 140 important ideas, 51%, 42% and 7% cover grade spans 9-12, 6-8, and 2-5, respectively. The proportion of benchmark-corroborated key ideas of each pool of items developed for every SFAA chapter used in this study, varies between 50% (*The Nature of Science*) and 68% (*The Physical Setting*).

Major points of similarity between the content of the test-items and that of benchmark statements are apparent in the sections in SFAA on the scientific world view, the universe, the earth, transformations of energy, the forces of nature, heredity, cells, life cycles (human identity), and mental health. In these content areas, at least seven out of ten scientific literacy test-items are also explicit benchmark statements. Thirty-six percent of test-items in the entire pool fall into this category. Key differences are evident in the section on scientific inquiry, evolution of life, and human development, where fewer than four out of ten test-items are also benchmark statements. The proportion of test-items in the pool in this category is 17%. Roughly half (i.e., between four and six out of ten) of scientific literacy test-items are also benchmark statements in the content areas related to the scientific enterprise, the nature of technology (science and technology, principles of technology, and technology and society), the forces that shape the earth, the motion of things, the diversity and interdependence of life, the flow of matter and energy, basic functions of the human organism, learning, and physical health. This category represents 47% of all scientific literacy test-items developed here.

In this research, sentences in *Science for all Americans* containing key ideas in, and attitudes toward, science were validated by acknowledged subject experts, and have given rise to test-items of scientific literacy that possess a substantial degree of content validity. Moreover, in a large proportion of these test-items, the content was corroborated by benchmark statements which were arrived at independently from this work and which contain the key ideas in science that students in particular grade spans need to understand on their way to becoming scientifically literate. To my knowledge, no other currently

available test-items of scientific literacy can match this degree of confidence that the items developed correspond to the major content areas of the theoretical concept they are designed to measure.

### *Item validity*

Item validity involves the consideration of two item features generally regarded as being important in the development of criterion-referenced tests: item-objective congruence and technical quality of items (Hambleton, 1984).

#### *Item-objective congruence*

Item-objective congruence is important because unless it can be shown with a high degree of confidence that the items in a criterion-referenced test measure the objectives they intended to measure, the usefulness of the test score information will be doubtful (Berk, 1984a; Hambleton, 1984). In the case of the test-item pool, each validated statement contained one or more important idea in, or attitude toward, science. These ideas and attitudes represent the objectives. Item-objective congruence was evaluated by a panel of judges and formed part of the evaluation of the technical quality of test-items (Appendix B, pp. 207-211). (Further details of this procedure are provided in the following section.) For each item, these judges were asked to read the validated statement from which the item was developed, and were then required to decide whether in their opinion the test-item substantially reflected the key or major concept expressed in the original statement. In the case of negative ratings (answers of "no" or "unsure"), judges were asked to provide a reason and to suggest changes in wording to the item. Items which were considered to have poor item-objective congruence were revised and modified. I am confident that a very high degree of item-objective congruency was achieved in all of the test-items developed.

#### *Technical quality*

The technical quality of test-items was reviewed by a panel of judges, consisting of local university lecturers in appropriate scientific disciplines with substantial experience in teaching first-year (i.e., freshman) classes. Thirty-three individuals were requested to participate. The response rate was 64%. Each judge reviewed the items of one chapter only. The number of judges that reviewed any one chapter ranged between two and five. Judges used a structured rating form, based on examples in Appendix C and D of Hambleton (1984), together with a set of guidelines on how to complete the rating tasks (Appendix B, pp. 207-211). The issues that the judges were asked to pay attention to are outlined below. To ensure that true and false versions of a test-item were matched, judges had to rate on a 5-point scale the extent to which the false version is probing understanding of essentially the same concept as the true



one. Versions which were poorly matched, that is, received a rating of “fair” or “poor”, were revised on the basis of comments and suggested changes in wording that the judges made.

Judges were asked to rate whether each true and false version of each item (a) tested only one concept or key idea, (b) was free of unnecessary scientific jargon, and (c) was free of vocabulary and/or sentence structure which may be difficult for the great majority of students entering tertiary education institutions. Judges were also asked to appraise whether in their opinion the words in each version would very probably have a common meaning for the great majority of first-year students, irrespective of background and home language. These questions were designed to eliminate as far as possible language from becoming a barrier to understanding the item, potentially resulting in incorrect answers for reasons other than inadequate science knowledge.

In case true and false versions were not perfectly true and false respectively, thus possibly raising uncertainty on the part of respondents as to the examiner’s standard of truth (Ebel & Frisbie, 1991), judges were requested to state whether they regarded the respective versions to be clearly true or false scientifically. They were also asked to decide whether versions were free of logical and scientific ambiguities. To ensure that false versions were not so ridiculously false as to be obviously wrong, even to those respondents who have received no science instruction, judges had to decide whether the false version of each item was plausible and appealing to respondents who did not know the correct answer. All comments and recommendations made by the judges were evaluated with care, and items were revised accordingly.

As has already been mentioned, it was undertaken to generate items with language demands appropriate for English second language speakers. After the technical quality of test-items had been evaluated, all items were reviewed by one experienced linguist working in science education and one English second language expert. Both were requested to review items with respect to sentence structure, grammar, punctuation, and appropriateness of vocabulary used (both scientific and non-scientific). Recommendations and suggestions were discussed with the language experts and items were revised accordingly.

## CONCLUSION

Through a series of carefully validated steps, 472 test-items for scientific literacy were generated; all are meticulously based on *Science for all Americans* - to my knowledge the only widely accepted document clearly identifying the skills, knowledge, and habits of mind to be attained in order to be regarded as scientifically literate. The items cover 240 important ideas in, and attitudes toward, science, of which an understanding was considered to form part of what it means to be scientifically literate by hundreds of

relevant experts. I believe these items possess a substantial degree of content, construct, and item validity, as well as high technical quality. The complete test-item pool is given in the Appendix C (pp. 213-233).

The test-items can be used for constructing measures of scientific literacy, or any of its dimensions, directed at a number of different target groups for a variety of purposes. Such tests could be uniquely valuable in a wide variety of planning functions in science education (e.g., see Champagne & Newell, 1992) and may open numerous important research avenues such as, for example, whether scientifically literate citizens are able to make 'better' decisions related to such issues as diet, health, consumer choices, and the environment (see Chapter 2 for a discussion of arguments commonly advanced for promoting of scientific literacy). Because of their true-false format and paper-and-pencil nature, the items are ideally suited for inexpensive and easy administration to large numbers of respondents.

The test-items are used here in the development of a *Test of Basic Scientific Literacy* which is being specifically constructed to measure competencies on all three constitutive dimensions of scientific literacy of a sample of individuals at the secondary-tertiary education interface in a particular South African context. The construction of this test instrument is described in the following chapter.



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## Chapter Four

# CONSTRUCTION OF A PAPER-AND-PENCIL *TEST OF BASIC SCIENTIFIC LITERACY*<sup>1</sup>

### INTRODUCTION

In reviewing existing composite measures of scientific literacy, it was argued in Chapter 3 that measures of this concept should ideally be based on items testing comprehension and awareness of important principles in, and attitudes toward, science on which there is widespread, documented agreement that these principles and attitudes form a substantial part of what it means to be scientifically literate. It was shown that the research methodology of Miller's and his colleagues' (Durant et al., 1989; Miller, 1992; NSB, 1989, 1991) was common amongst recent national and cross-national surveys of scientific literacy. However, the fact that measures of the nature of science and science content knowledge dimensions of scientific literacy in Miller's framework were based on a relatively small number of items with unspecified content validity, was believed to represent an important limitation of this methodology (Chapter 3). Moreover, it was argued that surveys of scientific literacy based on Miller's methodology are expensive and time-consuming to carry out because they employ face-to-face or telephone interviews. This interviewing strategy restricts such surveys' general, more widespread, use for less ambitious or less well-funded projects which may have only a small number of personnel available. The above two limitations thus motivated an alternative approach to assessing scientific literacy.

The generation of a pool of scientific literacy test-items based on selected literacy goals recommended by the AAAS in their publication *Science for all Americans* (SFAA) (AAAS, 1989) was described in Chapter 3. In the present chapter, I describe the construction of a paper-and-pencil *Test of Basic Scientific Literacy* (TBSL) from test-items selected from this item pool, and I outline the refinement of the TBSL for the specific purpose for which the test instrument has been developed.

In the construction of the TBSL, I have build on earlier work by Miller, Durant and their colleagues, but I have taken a different, essentially complementary, approach to measuring scientific literacy. The TBSL consists of three subtests, each corresponding to one of Miller's constitutive dimensions of scientific literacy, namely the Nature of Science Subtest (NSST), the Science Content Knowledge Subtest (SCKST), and the Impact of Science and Technology on Society Subtest (ISTSSST). Each subtest consists of a number of structured, selected response items which are based on selected scientific literacy

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1. This chapter has been published in a recent issue of *Public Understanding of Science* (see Laugksch & Spargo [1996]).

goals recommended in SFAA. The TBSL is thus designed to be an improvement and refinement of previous attempts to measure scientific literacy along the 'three constitutive dimensions' in a composite manner. In general, the construction of the TBSL was guided by the recommendations contained in Berk (1984a).

I first discuss the purpose of the TBSL and describe important characteristics and limitations of the test. Thereafter I offer suggestions as to what use the TBSL could be put, and I outline the item analyses and the selection of test-items. The validity of the TBSL is described thereafter, and I conclude this chapter by assessing the reliability of the test scores and the reliability of the mastery-nonmastery classification decisions.

### PURPOSE OF THE TBSL

In general, the purpose of the TBSL is to identify minimally scientifically literate high-school leavers, and the test has been constructed and validated for those South African matriculants who are entering tertiary educational institutions for the first time. It is important to point out again<sup>2</sup> that the scientific literacy of students is assessed in comparison to a particular, predetermined, model of scientific literacy: that of the AAAS as described in their overview report entitled *Science for all Americans* (Chapter 3). This report spells out the knowledge, skills and attitudes that all students should possess as a consequence of their total school experience, in order to be regarded as scientifically literate (AAAS, 1989; Chapter 3). More specifically, the purpose of the TBSL is to assess the extent, quality, and structure of the information base the AAAS recommends all high-school leavers should possess in order to be regarded as scientifically literate, as the items of which the test is composed were designed to test for comprehension of the facts and concepts that the AAAS consider to be an integral part of scientific literacy (Chapter 3). The TBSL also assesses whether matriculants possess particular beliefs with regard to the nature of science and the interaction between science, technology and society - beliefs that the AAAS has identified as forming part of scientific literacy (AAAS, 1989). Nevertheless, the TBSL is essentially testing only fundamental, or basic, aspects of scientific literacy. Knowledge of interdisciplinary concepts, applications of science, and the ability to apply knowledge for decision-making and problem-solving is not being tested by the items that comprise the TBSL (Chapter 3). Hence the test is called the *Test of Basic Scientific Literacy*. However, as was argued in Chapter 3, the extent of the students' information base is believed to be a vital component of scientific literacy, as it forms the foundation for all more sophisticated attributes of scientific literacy. Thus, despite the fact that the TBSL is acknowledged to have limitations, it is averred that the test developed here is an important step in assessing scientific literacy.

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2. In order to be explicit about what the TBSL does, it is necessary and logical to repeat here pertinent ideas already expressed in Chapter 3 (pp. 48).

The TBSL can be directed at a number of different target groups - consisting of individuals who are likely to have completed, or at least started, tertiary education (e.g., students, teachers, scientists, consumers, decision-makers, etc.) - for a variety of different reasons. Firstly, the test represents a potentially valuable tool in national and international assessments and comparisons of scientific literacy and extends the range of data-gathering strategies available for such surveys. Secondly, the TBSL will be useful in the identification of suitable populations which could be investigated for evidence of certain of the qualities and benefits that are generally assumed to result from scientific literacy (see Chapter 2 for a discussion of arguments for the promotion of scientific literacy). For example, does being scientifically literate in fact translate into 'better' decision-making, whether by key decision-makers (e.g., business leaders, parliamentarians, etc.) in terms of policy decisions, or by consumers with respect to such issues as diet, health, the environment, and consumer choices? Thirdly, scientific literacy of high-school leavers is increasingly acknowledged as being an important goal of science education throughout the world. The TBSL is also potentially valuable in a wide variety of planning functions in science education, where the test could be used to ascertain the degree to which secondary or tertiary education students are scientifically literate. Such studies would hopefully allow the identification of, for example, school and home variables that have an influence on scientific literacy. In this manner, key variables that may be amenable to direct intervention by science educators could be identified and thus assist in achieving widespread scientific literacy. Fourthly, given the historically racially-discriminatory education policies existing until recently in South Africa (Chapter 1), the TBSL may be useful in the identification of individuals or groups who require, or may benefit from, intervention strategies and programmes designed to promote the scientific literacy at the secondary/tertiary education interface. The TBSL may consequently also be useful as an indicator of the success of such intervention strategies and programmes in South Africa and elsewhere. Fifthly, the TBSL is a potentially helpful tool in identifying individuals suitable for admission to tertiary education in South Africa, and the test may also play an important role in the appropriate placement of such individuals. In general, therefore, the administration of the TBSL to a variety of different target groups can be used to describe patterns of scientific literacy, as well as to test hypotheses and to formulate new ones, all of which may be of interest and use to science and education policy-makers, science educators, and social science researchers.

In order for later users of the TBSL to be able to interpret responses to the test-items not only in terms of competencies on any of Miller's three dimensions of scientific literacy but also in terms of cognitive knowledge in particular content areas (this constitutes a further use of the scientific literacy test), the TBSL was constructed and validated as a criterion-referenced, or domain-referenced, test. (For a more detailed discussion of such tests see, for example Hambleton and Rogers [1991] and Nitko [1984].) *Criterion* in *criterion-referenced test* does not refer to a performance standard or cut-off score but rather to the domain of content to which the test scores are referenced (Hambleton & Rogers, 1991). Criterion-

referenced tests thus provide a basis for assessing the performance of examinees in relation to a set of clearly defined objectives, skills, or competencies (i.e., content) - that is, test scores are referenced *externally* - rather than in relation to other examinees (i.e., the 'norm' group), as is the case with norm-referenced tests in which test scores are referenced *internally* (Hambleton & Rogers, 1991). However, norm-referenced interpretations may still be drawn from scores on a criterion-referenced test.

The following sections deal with the actual construction and refinement of the TBSL. Item evaluation forms the first stage in the selection of items from the pool of scientific literacy test-items for inclusion in the test instrument, and is described next.

### PILOT TEST: ITEM EVALUATION

The generation of the scientific literacy test-item pool from which the TBSL items were selected has been described in Chapter 3. Once the test-items of the item pool had been deemed to be free of structural flaws (Chapter 3), they were evaluated to determine whether they actually function in the manner in which they were intended. The steps of this evaluation of test-items were based on guidelines recommended by Berk (1984b), and include the selection of criterion groups, gathering respondent feedback and computing appropriate difficulty and discrimination indices.

The first step relates to the selection of criterion groups for respondents to whom the test-items should be administered. As the purpose of the TBSL is to identify minimally competent matriculants along the three dimensions of scientific literacy, this step would in theory entail the selection of criterion groups designated as scientifically literate and illiterate respondents. However, if it was possible to identify the former group in a practical manner with relative ease and high degree of confidence, there would be little justification for the TBSL. In the absence of any comprehensive, inexpensive and reliable composite measures of scientific literacy appropriate for my purpose, an uninstructed-instructed groups approach was adopted. This is a technique which compares one group of individuals known by independent means to possess more of the specified trait (i.e., scientific literacy) with a second group known to possess less. This approach, however, assumes that an instructed individual equals a true minimally competent individual.

Pilot test-forms were administered to 966 full-time tertiary education students during one standard lecture period of carefully chosen science and humanities courses at a university, technikon, and college of education in Cape Town. Students registered for science courses were tested very much earlier in the academic year than students registered for non-science courses in order to reduce as far as possible the possibility that science students had reached an understanding of the relevant science concepts being measured at the tertiary, as opposed to the secondary, level. Because the imposed time limitation, and possible distortion of results due to test-fatigue, made it impractical - and indeed undesirable - for all

respondents to answer all the true and false 472 possible scientific literacy test-items, the items were randomly divided into four colour-coded pilot test-forms (PTa to PTd [Appendix D1 to D4, pp. 237-286]). Each form consisted of about 120 test-items, forms PTa and PTc, and PTb and PTd, covering identical content but in opposite test-item versions. Due to the way in which the test-items were allocated, forms did not contain both the true and false version of any item. In addition, respondents were required to answer on all forms a number of relevant questions with regard to their background (e.g., age, gender, home language, science subjects taken in senior high-school, etc.). During the pilot test administration, test-forms were distributed to seated students systematically and not randomly; in this way, all potential test-items were answered by some respondents. I believe that there is no known reason to question the randomness of the allocation which constitutes a series of systematic random samples.

In order to ensure uniformity, the pilot-test administrations were all carried out in a standardised manner and, in the vast majority of cases, by myself. In an introduction to students, the general purpose of the TBSL and pilot-test was explained and the importance of using the "Don't know" option when appropriate was stressed. Finally, all the students were urged to complete the test-items as best as they could. Feedback on the items was obtained in two ways. Students were requested verbally to mark any test-items that seemed to them to be confusing, unclear or ambiguous, and to underline words that they had difficulty understanding. In addition, whenever possible, informal student feedback was acquired through discussions with students at the end of the test administrations. The great majority of students completed all test-items within the allocated 45 minutes.

Although the advantage of the uninstructed-instructed approach is one of practicality, a difficulty of this approach is the definition of suitable criteria for identifying the groups and particularly how to define operationally the criterion of success. The two criterion groups were objectively identified *a posteriori* according to science instruction received in high-school. It is extremely difficult to find a large group of students enrolled at tertiary educational institutions in South Africa, irrespective of the students' course of study, who have taken no science subject at all in senior high-school. Hence, students who had taken two or more of the following science subjects which are offered widely in senior high-school were regarded as 'instructed': Agricultural Science, Biology, Geography, Physical Science, and Physiology. Those who had taken only one or no such science subject were regarded as 'uninstructed'.

The student sample used for the item evaluation needed to conform to the same profile as that of the anticipated target population (see Chapter 5). Hence, data of students who were older than 23 years, and those of students who had not matriculated within the last two years, were not used in the item analyses. After this sorting process, 414 individuals considered 'instructed' and 211 individuals considered 'uninstructed' remained (Table 4.1) and were used in the evaluation of test-items. Of the overall total of 625 students, 49%, 39%, and 12% were university, technikon and college of education students, respectively. There were no significant differences in the composition of the four pilot test-forms with



respect to population group and gender for each of the 'instructed' and 'uninstructed' groups. Hence the data of the four pilot test-forms were combined for each criterion group. There were no significant differences in the composition of the 'instructed' and 'uninstructed' group with respect to population group ( $\chi^2 = 3.29$ , d.f. = 2,  $p > 0.05$ ) and gender ( $\chi^2 = 0.178$ , d.f. = 1,  $p > 0.05$ ). Indian students were excluded from these two chi-square analyses because of the students' very low total frequency ( $< 15$ ).

**Table 4.1.** Number of students considered to be instructed and uninstructed in science who completed different Pilot Test-forms.

PT Form	Instructed	Uninstructed	Total
A	100	51	151
B	96	54	150
C	115	55	170
D	103	51	154
Total	414	211	625

The item difficulty index for instructed and for uninstructed students was compared for each item of each pilot-test form. These indices were computed as the percentages of students who correctly answered the item (Berk, 1984b). The index of item discrimination measures the differences in performance between the instructed and uninstructed groups. Any differences that occur were presumed to be attributable to the effect of instruction (Wedman, 1973, 1974; cited by Berk, 1984b). Of the vast array of different discrimination indices found in the literature and reviewed by Berk, only one index for uninstructed-instructed groups was rated highly in terms of ease of computation and meaningfulness in the context of the test development process (Berk, 1984b). This was the uninstructed-instructed group difference ( $DIS_{UGD}$ ), defined as the proportion of students in the instructed group who answered the item correctly minus the proportion in the uninstructed group who answered it correctly. This index is not sensitive to individual performance variation but only to total group loss or gain, and values range between -1 and +1.

## ITEM SELECTION

The selection of test-items to be included in all three subtests in the final TBSL form was based on a number of criteria suggested by Berk (1984b). Item-objective congruence is of paramount importance to the effectiveness of the total test and was evaluated positively for all items in the scientific literacy test-item pool (Chapter 3). In general, items should be more difficult for the uninstructed group (index value 0 - 50) than for the instructed group (index value 70 - 100). Items should also positively discriminate between criterion groups and have a high, positive index value.

Item discrimination builds into a test the property of decision validity (Hambleton, 1984) which is reflected in the accuracy with which students are classified as competent and incompetent on particular objectives (Berk, 1984b). Selecting only items that best discriminate would produce the best test in terms of decision. This would, however, occur at the expense of content validity, as items associated with particular objectives would be systematically discarded if their discrimination indices were low. Items for inclusion in the final TBSL form were therefore selected on the basis of item statistics *and* relevance of content. A measure of the relevance of item content was obtained from the importance ratings which Fellows of the Royal Society of South Africa were asked to assign to the key ideas in science identified from the SFAA text in the initial phase of the development of the test-item pool (see Chapter 3). Once Fellows had identified key ideas of “undisputed significance to science” in the entire SFAA chapter allocated to each of them, the Fellows were asked to place each idea into the following three categories of importance: “very important”, “important”, and “relatively less important”. For each item, the number of ratings in the three categories were summed; the item’s final importance rating was determined by the category with the highest number of ‘votes’. Tied rankings resulted in the middle, that is “important”, category being chosen for that item. Student feedback from the pilot test, in both written and verbal form, allowed me to identify test-items which were ambiguous for a number of different reasons, or contained difficult vocabulary. These items were not considered for inclusion in the final test form.

The final form of the TBSL consists of 110 items; 22, 72 and 16 test-items for the Nature of Science Subtest (NSST), the Science Content Knowledge Subtest (SCKST), and the Impact of Science and Technology on Society Subtest (ISTSST), respectively. The distribution of the number of test-items among the science content areas of the TBSL is comparatively even, with the life sciences and the nature of science containing the most, and the physical and chemical sciences containing the fewest, test-items (Table 4.2). The total number of true and false test-items is 63 (57%) and 47 (43%), respectively (Table 4.2).

**Table 4.2.** The number of TBSL test-items per science content area, including respective numbers of true and false items and the respective median discrimination index ( $DIS_{UIGD}$ ).

Content area of TBSL	No. of test-items	Proportion of total (%)	No. of <i>True</i> test-items	No. of <i>False</i> test-items	Mean $DIS_{UIGD}$
Nature of science	22	20	14	8	11.3
Earth/space sciences	15	14	6	9	12.3
Physical/chemical sciences	14	13	11	3	14.0
Life sciences	24	22	15	9	16.2
Health sciences	19	17	8	11	12.8
Nature of technology	16	14	9	7	7.2
Total	110	100	63	47	12.8

The complete test instrument is given in Section B of the survey questionnaire (Appendix G, pp. 309-330). Survey questions 53-74 and 99-114 form the NSST and ISTSST, respectively. Questions 38-52, 75-98, 115-128, and 129-147 correspond to the earth/space sciences, physical/chemical sciences, and life and health sciences, respectively, and together form the SCKST. The sequencing of items within content areas of the TBSL corresponded to the succession of science concepts presented in the relevant chapters of SFAA. Beginning with possibly the most familiar and hence apparently 'easiest' items (i.e., the earth/space sciences) in order to boost the confidence of respondents, content areas in the TBSL were sequenced as to alternate between familiar and potentially more difficult or controversial areas.

Values of the difficulty index of the selected test-items in the seven content areas ranged from 66 to 83 for the instructed group, and from 54 to 68 for the uninstructed group. The mean difficulty index of all test-items in the final TBSL form was significantly higher for the instructed group than for the uninstructed group ( $n = 110$ ,  $t = 6.08$ ,  $p < 0.0001$ ). The discrimination index ( $DIS_{UGD}$ ) for all test-items included in the TBSL was positive, ranging from 0.1 to 27.8. The overall TBSL mean discrimination index was 12.8, and the mean discrimination index for test-items in the various science content areas ranged between 7.2 (the nature of technology) and 16.2 (physical and chemical sciences) (Table 4.2). The above discrimination indices may appear to be comparatively small, however the importance of the difficulty indices determined above lies in the effect of summation. As the number of items per content area increases, and - for the case of any fixed number of items - as the number of individuals in the instructed and uninstructed groups increases, it is more likely that differences between the average combined items scores per content area of each group as may actually exist, are detected. Given the relatively large number of items per content area, and the comparatively large number of individuals per criterion group, it is averred that the determined discrimination indices are 'real'. Furthermore, students of the 'uninstructed' criterion group were not truly uninstructed in science, as 85% of the individuals in this group had taken one science subject in senior high-school. (The difficulty of finding students enrolled at tertiary educational institutions in South Africa who have taken no science subject at all in senior high school was pointed out earlier in this chapter.) It is therefore not unreasonable to believe that the discrimination indices given in Table 4.2 represent conservative values, and that discrimination indices for items presented to criterion groups of instructed and truly uninstructed students would indeed be higher.

The number of TBSL test-items rated by Fellows of the Royal Society of South Africa as covering "very important", "important", and "relatively less important" ideas in, and attitudes toward, science are 51 (46%), 48 (44%), and 6 (5%), respectively. Five of the items test for comprehension of key ideas in science that were not rated by the Fellows. Of the original 240 key ideas, 36 (41%), 81 (63%), and 9 (60%) rated as "very important", "important", and "relatively less important", respectively, were not included in the TBSL. Of those scientific literacy test-items excluded (both true and false versions), the

overwhelming majority was eliminated because of negative discrimination indices, inappropriate item difficulty indices (i.e., items were either too difficult or too easy), and various difficulties encountered with these items by respondents during the pilot test.

The TBSL thus contains scientific literacy test-items that cover a broad range of different content areas, that discriminate positively between students instructed and uninstructed in science, and that test for understanding of important ideas in, and attitudes toward, science.

## VALIDITY

A key and very significant attribute of any rigorous test instrument is the requirement that the instrument actually measures what it is intended to measure, that is, that the instrument contains items that are valid. This validity requirement is a constant, major concern, not least because an instrument's reliability is very much influenced by its validity. Forms of validity that are relevant to the construction of the TBSL are content, item, and construct validity. Aspects of the former two forms of validity have been evaluated in detail in the development of the pool of scientific literacy test-items on which the TBSL is based (Chapter 3), and will thus only be summarised here. Construct validity and further pertinent aspects of content validity are discussed below.

### Content validity

Content validity focuses upon the extent to which the content of an indicator corresponds to the content of the theoretical concept it is designed to measure (Hambleton, 1984; Zeller, 1994). The first aspect of content validity that needs to be evaluated is thus whether the content 'universe' addressed by the test is appropriate (Shepard, 1993). The constituent test-items of the TBSL and its subtests were selected from a pool of test-items based on SFAA. This publication contains the final recommendations of the AAAS in response to the question "what understandings and habits of mind are essential for all citizens in a scientifically literate society" (AAAS, 1989, p. 3). Four-hundred-and-sixty scientific panel members, consultants, reviewers, and advisors were involved in the various stages of establishing these final recommendations which spell out the knowledge, skills, and attitudes all high-school leavers should possess in order to be regarded as scientifically literate (AAAS, 1989; Chapter 3). (This figure is an overestimate, as some reviewers, consultants, and advisors participated in more than one stage of the development of SFAA [AAAS, 1989; Chapter 3].) The item pool is thus based on a substantial degree of consensus in the scientific community in the United States on what it means to be scientifically literate, and test-items therefore possess a discernible degree of content validity (Chapter 3). As the TBSL is based on test-items selected from this pool, it is averred that the TBSL possesses an equally substantial

degree of content validity. However, a potential limitation is the fact that the test does not include measures of all aspects of scientific literacy delineated by SFAA, as the original test-item pool was only based on selected chapters of SFAA corresponding to Miller's three-constitutive dimensions of scientific literacy (Chapter 3). In particular, ideas and concepts related to mathematics; "habits of mind"; common themes that pervade science, mathematics and technology; significant discoveries; and major human activities that have shaped our environment and lives are not covered by the TBSL (AAAS, 1989).

**Table 4.3.** A comparison of the proportion of key ideas in science (out of 240) contained in the different chapters of SFAA with the proportion of test-items (out of 110) included in the TBSL from corresponding content areas.

<i>Chapter:</i> Content area	Proportion of total no. of key ideas (%)	Proportion of TBSL test-items (%)
<i>The Nature of Science</i> Nature of science	17.5	20.0
<i>The Physical Setting</i> (Part I) Earth/space sciences	17.9	13.6
<i>The Physical Setting</i> (Part II) Physical/chemical sciences	12.9	12.7
<i>The Living Environment</i> Life sciences	19.6	21.8
<i>The Human Organism</i> Health sciences	18.3	17.3
<i>The Nature of Technology</i> Nature of technology	13.8	14.6

The second aspect of content validity that needs to be evaluated is whether the sample of items selected from the domain or 'universe' of test-items is adequate (Shepard, 1993). A comparison of the proportion of key ideas in science contained in the selected chapters of SFAA with the proportion of test-items included in the TBSL from the corresponding content areas shows that the proportions are very similar (Table 4.3). This comparison shows that no content area is particularly over- or under-represented in the TBSL, indicating that the items selected for the TBSL sample the domain of possible scientific literacy test-items in a manner consistent with the apparent structure of SFAA. Logical analyses of test content therefore lead one to believe that, even with the possible limitations mentioned above, the TBSL possesses a high degree of content validity.

### Item validity

In the construction of the TBSL, item validity involved the consideration of two item features generally regarded to be important in criterion-referenced tests: item-objective congruence and technical quality of

items (Hambleton, 1984). Both these aspects of item validity were extensively discussed in the development of the original scientific literacy test-item pool (Chapter 3, pp. 59-60), and will therefore not be dealt with here.

### Construct validity

This type of validity “focuses on the assessment of whether a particular measure relates to other measures consistent with a theoretically anticipated way” (Zeller, 1994, p. 6572). Independent corroboration of the validity of the specific key ideas in science tested for in the test-items included in the TBSL is evident from *Benchmarks for science literacy* (AAAS, 1993; Chapter 3). This publication is the product of Phase II of *Project 2061*, and reformulates the goals for scientific literacy of each SFAA chapter into intermediate levels of understanding for grade spans K-2, 3-5, 6-8, and 9-12, corresponding approximately to ages 5-7, 8-10, 11-13, and 14-17, respectively (AAAS, 1993; Chapter 3). *Benchmarks* had not yet been published when the pool of scientific literacy test-items from which the TBSL was constructed, was developed. Nevertheless, 60 (55%) of the 110 key ideas in, and attitudes toward, science covered in the TBSL are contained in *Benchmarks* as explicit benchmark statements. These statements are specified thresholds that describe the level of understanding expected to be reached at certain school levels by all students on their way to becoming scientifically literate (AAAS, 1993). Of those 60 important ideas, 52%, 42% and 7% cover grade spans 9-12, 6-8, and 2-5, respectively. The proportion of benchmark-corroborated key ideas of each content area of the TBSL varies between 36% (nature of science) and 63% (health sciences).

Major points of similarity between the content of the test-items included in the TBSL and that of benchmark statements are apparent in the sections in *Benchmarks* on designs and systems (principles of technology), forces (processes) that shape the earth, transformations of energy, the forces of nature, heredity, cells, interdependence of life, human identity, learning, and physical and mental health. In these areas, at least seven out of ten scientific literacy test-items are also explicit benchmark statements. Forty percent of test-items of the entire TBSL fall into this category. Key differences are evident in the section on the scientific enterprise, motion (of things), diversity and evolution of life, human development (life cycles), and basic functioning. In these areas fewer than four out of ten test-items are also benchmark statements. The proportion of test-items in the pool in this category is 23%. Roughly half (i.e., between four and six out of ten) of the scientific literacy test-items in the TBSL are also benchmark statements in the discipline areas related to the scientific world view, scientific enquiry, technology and science, issues in technology (technology and society), the universe, the earth, the structure of matter, and the flow of matter and energy. This category represents 41% of all scientific literacy test-items developed here.

The TBSL is thus constructed from test-items that were based on key ideas in, and attitudes toward, science contained in SFAA - a document that was earlier shown to possess a substantial degree of content validity. Although not representing every aspect of scientific literacy contained in SFAA, the test-items used in the TBSL sample the domain of possible test-items in equal proportion to the content areas of the test-item pool. Moreover, in a large proportion of the TBSL test-items, the content was corroborated by benchmark statements which were arrived at independently from this study and which contain the key ideas in science that students in particular grade spans need to understand on their way to becoming scientifically literate. To my knowledge, no other currently available composite measure of scientific literacy can match this degree of confidence that the test-items used in such an instrument correspond to the major content areas of the theoretical concept they are designed to measure.

In order to confirm that the various test-items in each of the three subtests of the TBSL in fact measure the relevant unobservable underlying dimension of scientific literacy they are designed to measure, it would be helpful to conduct a factor analysis of the test-items. This strategy would further aid our understanding of the TBSL and represents an avenue for possible further research on the development of the *Test of Basic Scientific Literacy*.

## PERFORMANCE STANDARD

When tests are used to distinguish between the competent and incompetent, a cut-off point is essential. The cut-off point used is clearly an extremely important attribute of a test, as the validity of the final classification decision depends not only on the validity of the test content, but also very much on the validity of the standard (i.e., cut-off point) used in this classification (Shepard, 1984). Setting a valid, defensible performance standard for each of the subtests of the TBSL is therefore crucial to the test's value and usefulness.

## Selection of judges

Members of key South African professional science and engineering associations were asked to act as judges in the standard-setting process. Participating associations were the South African Chemical Institute, the South African Geographical Society, the South African Institute of Ecologists,<sup>3</sup> the South African Institute of Physics, and the three South African institutes of civil, electrical and mechanical engineers. Latest available membership lists were supplied by each participating association, and only Ordinary members, Fellows, or Honorary Fellows were used in the standard-setting procedure. All

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3. This professional science association has recently extended its scope and has been renamed the Southern African Institute of Ecologists and Environmental Scientists.

associations have entrance criteria for admitting individuals as Ordinary members; Fellows are senior members and need to apply or be nominated to be graded as such, and Honorary Fellows are normally senior members or ‘outsiders’ with a considerable and distinguished track record. Honorary Fellows are usually elected or nominated to this grade.

**Table 4.4.** Summary of the category of membership and of the methods used in selecting members of professional science and engineering associations as potential judges for setting a performance standard for the TBSL.

Professional association	Membership category	Selection method	Attribute
SA Institute of Physics	Ordinary	all	with stated interest in education
SA Chemical Institute	Ordinary	random	with stated interest in education
SA Institute of Ecologists	all	all: random:	with stated interest in education remaining members
SA Geographical Society	all	random per Province	excluding teachers
SA Inst. of Civil Eng.	Fellows Hon. Fellows	all	Western Cape members only
SA Inst. of Elec. Eng.	Fellows Hon. Fellows	all	
SA Inst. of Mech. Eng.	Fellows Hon. Fellows	all	

Members of the South African Institute of Physics and the South African Chemical Institute, as well as certain members of the South African Institute of Ecologists, with a special interest in education were identified either by the Education Committees of the respective associations, or through an entry in the education category of the ‘interest’ field for members in the associations’ database. Members of the South African Geographical Society who were teachers were excluded from being selected, as it was believed that being intimately involved with high-school students may result in teachers confusing what student *should* be able to do with what students *are* able to do. For logistic reasons, permission was given to approach only Western Cape members of the South African Institute of Civil Engineers. In very large associations - those with 200 or more members - potential judges were selected at random, whereas in smaller associations or those where members had been pre-selected, all members were selected. Table 4.4 gives a summary of how members were selected, and details the category of members selected to participate as judges in the standard-setting procedure for the TBSL.



The seven selected professional associations together cover the major content areas of the TBSL (Table 4.5). Test-items for the health sciences were related to human identity, the human life cycle, the basic functioning of the human body, learning, as well as physical and mental health. These items are, therefore, largely concerned with general biology related to humans, and members of the South African Institute of Ecologists - who are almost exclusively life scientists - were deemed appropriate to act as judges in this content area.

**Table 4.5.** Content areas of the scientific literacy test-items and the combined total number of members from corresponding professional associations which participated in setting a performance standard for these items.

Content area	Professional associations	Combined total no. of members*
Nature of science	SA Institute of Physics SA Chemical Institute SA Institute of Ecologists SA Geographical Society	123
Earth/space sciences	SA Geographical Society	37
Physical/chemical sciences	SA Institute of Physics SA Chemical Institute	72
Life sciences	SA Institute of Ecologists	61
Health sciences	SA Institute of Ecologists	46
Nature of technology	SA Inst. of Civil Engineering SA Inst. of Elec. Engineering SA Inst. of Mech. Engineering	74

\* Some members set performance standards for test-items in two content areas (see text)

It would have been unreasonably demanding in terms of time to ask all judges to set a performance standard for all 110 test-items. Return rates may also have been affected negatively for this reason. Judges were therefore only requested to rate the items falling within their own area of expertise (Table 4.5). Members of associations in the natural sciences, however, additionally set performance standards for test-items on the nature of science (Table 4.5). Personal experience leads me to believe that the majority of natural scientists will have deliberated carefully upon the nature of science during their career, and thus would have worthwhile insights in this area.

### Procedure for setting the performance standard

All standard-setting techniques ultimately rely on human judgement, as standards are derived from judgement about what examinees *should* be able to do (Berk, 1986; Shepard, 1984). The difficulty lies in

having to locate a point on a continuum where unacceptable performance (i.e., incompetence) switches to acceptable (i.e., competence). A classification cut-off score for each subtest was determined using the Angoff procedure, a recommended standard-setting procedure for criterion-referenced tests (Angoff, 1971; cited in Shepard, 1984). In this procedure, judges are asked to assign to each test-item a probability which is the likelihood that a minimally competent examinee will answer the item correctly. Details of this procedure are given below.

The judges - selected in the manner described above - were given written, step-by-step instructions on how to complete the standard-setting task, as well as a description of the context in which they were asked to set a standard for the respective dimensions of scientific literacy (see Appendix E1, p. 289). This description consisted of the following elements: the conceptual definition of scientific literacy used here (see Chapter 2, p. 41); a description of the envisaged need for scientific literacy in South Africa, and a description of the purpose of the scientific literacy test. These steps were taken to limit the potentially overly great influence on each judge's standard-setting task of personal differences in perceptions about the test's required function. In the Angoff procedure, judges are asked to assign to each test-item a probability which is the likelihood that a minimally competent examinee will answer the item correctly (Angoff, 1971; cited by Shepard, 1984). Judges were requested to carefully read each test-item and were asked to imagine a group of 100 minimally scientifically literate examinees (see Appendix E, pp. 287-290). They were then required to state how many examinees in this group should be able to answer each item correctly. The stated number divided by 100 is the judged probability that a minimally scientifically literate matriculant will answer the test-item correctly.

The 713 members of professional science and engineering associations selected in the above manner were requested in writing to participate in the setting a performance standard for the TBSL. Two-hundred-and-fifty-eight members replied, yielding an overall response rate of 36% for the combined associations. The number of judges used per content area of the TBSL ranged between 37 and 123 (Table 4.5).

The data of judges who did not state a probability for *all* test-items contained in their assigned content area were eliminated from the calculation of the performance standard. The probabilities allocated by each judge to items within each judge's content area were summed to yield a minimally scientifically literate cut-off score for each content area per judge. An overall cut-off score per content area was then established by calculating the median value of the judges' cut-off scores per content area. The performance standard of each subtest of the TBSL was finally derived by summing the overall cut-off score of the constituent content areas per subtest.

The use of the median rather than the mean was decided upon because in almost every content area there were some test-items for which the probability assigned by different judges were observed to vary widely. The median is less sensitive than the mean to large fluctuations in the value of a variable (Zar,

1984), and for this reason the median was believed to be more appropriate than the mean in the determination of the cut-off score per content area. The lower end-point of the two-sided 95% confidence interval around the median overall cut-off score for each area, rounded downwards to the nearest integer, was used in the calculation of the performance standard. For details of the calculation of the confidence interval around the median see Zar (1984).

The performance standard for the Nature of Science, Science Content Knowledge, and Impact of Science and Technology on Society Subtests was thus calculated to be 13, 45, and 10, respectively. These standards mean that in order to be regarded as minimally scientifically literate, a matriculant would have to obtain at least 13 out of 22, 45 out of 72, and 10 out of 16, on each of the above subtests of the TBSL, respectively. The TBSL is marked dichotomously, with one mark being awarded per question for a correct answer, and zero for a wrong answer (or a "Don't know" response). The correct number of answers per subtest are summed to form the total score per subtest which, when added, form the overall TBSL score.

Under the assumption of arbitrary choices from the three options for each item, the chance that the above performance standards could be obtained by blind (i.e., random) guessing alone is exceedingly small, as the influence of blind guessing diminishes as a test increases in length. The chance of obtaining a score equal to the required performance standard on the NSST subtest is 12 in 1000, that on the SCKST is 12 in 10000, and finally 16 in 1000 for the ISTSST. The chance of meeting the performance standard on *all* subtests - and hence being classified scientifically literate for the purpose of this study - is consequently about 2 in  $10^7$ . This approach to modelling the probabilities of obtaining the performance standards from binomials with probability parameter 1/3 is presumed to be reasonable on the basis that the importance of a "Don't know" answer was stressed in both the pilot and administrative phases (see pp. 67 and 95).

A contrasting view may arise if one considers a worst-case scenario of an examinee who is guessing with equal probability between the true and false option of each item. Then the probability of a purely random guesser being declared scientifically literate is the product of the binomial probabilities (with parameter 1/2) for each subtest: 0.2617, 0.0222, and 0.2272 for the NSST, SCKST, and ISTSST, respectively. These figures translate to about 13 per 1000 - or an error rate of less than 1.5% - in misclassifying such a person as scientifically literate.

Ebel and Frisbie (1991) suggested the use of a "Don't know" option as a strategy in the construction of items which would diminish the probability of a single random guess option being correct. Even if this does not occur, any use of the "Don't know" option will effectively reduce the number of items answered and hence make it more difficult to achieve a particular performance standard on purely random guesses. The net effect is that the use of a "Don't know" category in the format of the items will reduce the probability of a random guesser being classified as scientifically literate. The "Don't know"

category was also retained in the item format despite evidence suggesting that girls are more likely to use this option than boys (e.g., Linn et al., 1987). Such a potential effect was nevertheless deemed to be an acceptable trade-off for the likelihood of obtaining fewer misclassifications due to random guessing. The non-homogeneous character of the South African population is, however, likely to complicate potentially different gender responses, and a differential response to the “Don’t know” option could conceivably also apply to members of different population groups with different educational and test-taking experience. The complexity of the South African context requires comparatively sophisticated analyses in order to detect any valid differential responses to “Don’t know” options with respect to gender and population group, and such analyses provide potentially fruitful directions for further research.

The decision with respect to the inclusion of the “Don’t know” category had to be made *a priori* in the test construction. In a *post factum* analysis of the responses it was found that 339 out of 4227 examinees tested (see Chapter 5 for details of the present survey) deliberately did not make use of the “Don’t know” option in any of the 110 items answered. Of this group, 228 and 111 were classified as scientifically literate and illiterate, respectively. If test scores meeting the performance standard, and test scores of one point above the performance standard, are regarded as an arbitrary yet comparatively broad borderline definition, then 68 individuals in the former group are borderline classifications with respect to being scientifically literate. This proportion is higher than expected. However, its interpretation is not clear as all borderline cases are unlikely to have been classified as scientifically literate on account of random guessing alone. For example, factors related to the examinees’ background and course of study are possible other important influences. Rather than modify the performance standards derived empirically from South African scientists and engineers, the existing standards were used. Further exploration of borderline effects, however, provides useful directions for further research.

Examinees who adopt an alternative answering strategy to blind guessing such as, for example, answering items as either all true or all false, would not meet the performance standard on two of the three subtests. As is clear from columns three and four in Table 4.2, examinees adopting the all-true strategy would obtain a score of only 14, 40, and 9 on the NSST, SCKST, and ISTSST, respectively, whereas examinees adopting the all-false strategy would obtain a score of only 8, 32, and 7 on these respective subtests. Given that the performance standard for the Nature of Science, Science Content Knowledge, and Impact of Science and Technology on Society Subtests was set at 13, 45, and 10, respectively, examinees employing the all-true/all-false answering strategy would not be classified as scientifically literate.

From the above discussion of different uninformed answering strategies it is concluded that a scientifically literate classification due to meeting the performance standards set from the judgements of members of South African professional science and engineering societies will only rarely be achieved by those examinees who actually have no relevant scientific knowledge. The issue of whether the standards

can be attained by those examinees with only a little scientific knowledge is addressed differently, and to this end empirical evidence for appropriate discrimination between criterion groups is discussed next.

### **Validation of performance standard**

Once performance standards had been established, evidence as to the validity of these standards was gathered. This evidence was based on a 'contrasting groups' method (Zieky & Livingston, 1977; cited by Shepard, 1984) in which the final TBSL form was administered to 'known' competent and incompetent students. This method is analogous to known-groups validation whereby the diagnostic validity of a test is established with known cases (Shepard, 1984). The validity of the performance standard depends on the proportions of hypothesised and actual competent and incompetent classifications: validity will be enhanced if, for example, the proportion classified incompetent is in keeping with the proportion of 'known' incompetent students.

It would seem methodologically prudent to accumulate evidence with respect to the validity of the performance standard from a variety of criterion groups in different educational contexts, as it is unlikely that such validity can be established beyond doubt by using one set of contrasting criterion groups in any one particular educational setting. Such a suite of validation studies is beyond the scope of this thesis, and presents directions for further research. Nevertheless, one carefully chosen set of criterion groups will in all probability give an indication of the validity of the performance standard. This latter strategy has been employed here.

The 'known' competent group was represented by a section of the top-100 competitors of the South African National Youth Science Week, commonly known as the science olympiad, which is organised by the Foundation for Education, Science and Technology (FEST). This high-school science contest is held nation-wide every year for students in their last three years of high-school, and participants need to complete a battery of multiple-choice test-items in a General section and in either a Biology or Physical Science section. The TBSL was administered to 81 and 63 students by FEST staff during the traditional annual meeting of the 100 top-placed contestants in 1994 and 1995, respectively (see Appendix F [pp. 291-308] for the survey questionnaire used). Students had 45 minutes to complete the scientific literacy test. Once the 1995 data of students who were placed in the top-100 positions of the contest in both years - and thus wrote the TBSL twice - were eliminated, 57 individuals remained in this science olympiad group.

The 'known' incompetent criterion-group was represented by 68 and 59 first-year students registered at a local college of education in 1994 and 1995, respectively. In each year, the TBSL was administered to the College group during a standard 45 minute lecture period (see Appendix G [pp. 309-330] for the survey questionnaire used). These students were - according to the experienced college lecturer -

performing well in their other subjects but not in Science. It was therefore assumed that the two criterion-groups were generally comparable in most aspects except science performance. Once the data of students who did not fit the profile of the target population of the TBSL (i.e., entering tertiary education for the first time and not older than 23 years of age) were eliminated from the College group, 74 individuals remained.

There were some differences in the final composition of both criterion groups with respect to gender and age. Although 86% of the individuals in the science olympiad group were male whereas the majority of students in the College group was female (76%), in neither the former (Fisher's Exact Test [two-tailed],  $p > 0.05$ )<sup>4</sup> nor the latter group ( $\chi^2 = 0.29$ , d.f. = 1,  $p > 0.05$ )<sup>5</sup> was there any significant association between gender and competence in scientific literacy. As was to be expected, the mean age of students in the College group (19.9 years) was higher than that of individuals in the olympiad group (17.5 years).

Individuals in both groups were classified as competent (i.e., scientifically literate) or incompetent (i.e., scientifically illiterate) with reference to the performance standard for the TBSL set above. In both the science olympiad ( $\chi^2 = 14.50$ , d.f. = 1,  $p < 0.0005$ ) and College criterion group ( $\chi^2 = 4.09$ , d.f. = 1,  $p < 0.05$ ) there was a significant difference in the proportion of Black and White students who were classified as competent and incompetent. (The majority of students are English Second Language speakers, and this difference may indicate that the TBSL is potentially not language robust. The investigation of this aspect of the TBSL provides directions for further research in the refinement of the TBSL, and has been partially addressed in Chapter 6 [p. 116-117].) Hence, the TBSL performance standard was validated separately for these two groups of students. Based on 33 'known' competent and 28 'known' incompetent individuals (Table 4.6), there was a significant association ( $\chi^2 = 15.62$ , d.f. = 1,  $p < 0.0001$ ) between criterion group and competency classification for Black students. Similarly, based on 105 'known' competent and 46 'known' incompetent individuals (Table 4.6), there was a significant association ( $\chi^2 = 53.33$ , d.f. = 1,  $p < 0.0001$ ) between criterion group and competency classification for White students. Gamma ( $\Gamma$ ) - a measure of agreement between row and column classifications - was large and positive in both cases ( $\Gamma = 0.87$  and  $\Gamma = 0.91$  for the Black and White group, respectively), indicating that the strength of the association between criterion group classification and scientific literacy competency classification based on the TBSL was high for both the Black and White groups, and that the data in each of the two contingency tables represented in Table 4.6 tend to lie in the upper left and lower right cells. As hypothesised, more individuals from the science olympiad group than from the College group were classified as scientifically literate (Table 4.6).

4. The frequencies were insufficiently large to use a chi-square analysis, and hence the Fisher's Exact Test was used (see Everitt, 1992).

5. In this chapter, the Yate's continuity correction is used for the analysis of all  $2 \times 2$  contingency tables.

**Table 4.6.** The number of competent and incompetent classifications for Black and White students made in two criterion-groups on the basis of the performance standard set for the TBSL.

Population group	Criterion group	Scientificall literate ( <i>competent</i> )	Scientificall illiterate ( <i>incompetent</i> )	Total
Black ( <i>n</i> = 61)	Science Olympiad ( <i>competent</i> )	21	12	33
	College ( <i>incompetent</i> )	3	25	28
White ( <i>n</i> = 151)	Science Olympiad ( <i>competent</i> )	97	8	105
	College ( <i>incompetent</i> )	16	30	46

Similarly, more individuals from the College group than from the science olympiad group were classified as scientifically illiterate (Table 4.6). Actual competent and incompetent classifications are thus generally appropriate for both the Black and White groups. These results provide evidence that the performance standard for the TBSL, decided on the basis of expert opinion, is, in fact, reasonable and hence likely to be valid.

## RELIABILITY

Criterion-referenced test scores are generally used either to make inferences about levels of proficiency, or to make mastery-nonmastery decisions (Hambleton & Rogers, 1991). Two classes of reliability are of importance in evaluating the consistency of criterion-referenced tests such as the TBSL. The first one is the consistency of individual test-scores across parallel or randomly parallel test forms, that is, the *internal* consistency of a test (Berk, 1984c). The second class relates to the consistency of mastery-nonmastery classification decisions across repeated measures with one test form or parallel test forms (Berk, 1984c). The reliability of the TBSL is evaluated separately for each of the above classes, though the intended use of the TBSL clearly falls into the mastery-nonmastery category.

### Reliability of test-scores

Although it has been argued that in criterion-referenced tests the consistency of an examinee's test-score is not as important as whether an examinee is consistently assigned to the same classification during

repeated testing (Hambleton & Novick, 1973), the reliability (i.e., internal consistency) of test-scores is nevertheless important. Calculation of the internal consistency of the TBSL was based on a single test administration ( $N = 4227$ ) to first-time entering students registered at the five major tertiary educational institutions in the Western Cape (i.e., the present survey which is described in Chapter 5 in detail). Reliability of the test-scores was estimated by the Kuder-Richardson 20 coefficient ( $\alpha_{20}$ ), appropriate for tests where all items are scored either 0 (wrong) or 1 (right). The Kuder-Richardson 20 coefficient is calculated by

$$\alpha_{20} = \frac{k}{k-1} \left[ 1 - \frac{\sum p(1-p)}{V} \right]$$

where  $k$  is the number of test-items,  $p$  is the proportion of students answering a question correctly, and  $V$  is the variance of total test scores. (For further details see Livingston [1988]). As the TBSL consists of three subtests, each measuring different attributes, the test is not necessarily homogeneous, that is, not all TBSL test-items are designed to measure a single, common latent attribute. (Taken *together*, however, the three subtests measure scientific literacy). Hence, the internal consistency of each subtest - homogeneous in what it measures - was determined individually (Thorndike, 1990). The reliability of the test-scores of the three subtests making up the TBSL, as well as that of the score of the complete TBSL, is given in Table 4.7. As reliability is, amongst other things, affected by the length of a test (Berk, 1984c; Carmines & Zeller, 1979), the number of test-items per subtest is also given for reference in Table 4.7.

The reliability coefficient of the TBSL is large for reasons associated with the relatively high values of  $\alpha_{20}$  for the constituent subtest, together with the high positive correlation between scores on those subtests, and hence also with the TBSL scores (Table 4.8). It is therefore inferred that the TBSL is reliable in the sense of being internally consistent between its items and constituent parts in measuring something akin to a single common latent attribute, labelled here as scientific literacy.

**Table 4.7.** The internal consistency ( $\alpha_{20}$ ), standard error of measurement ( $\sigma(\Delta)$ ), and measurement coefficient of variation (CV) of the TBSL and its constituent subtests, together with the respective number of test-items for each subtest.

Subtest/Test	$\alpha_{20}$	$\sigma(\Delta)$	CV (%)	No. of test-items
Nature of Science Subtest(NSST)	0.73	2.2	17	22
Science Content Knowledge Subtest (SCKST)	0.94	3.8	8	72
Impact of Science and Technology on Society Subtest (ISTSST)	0.78	1.8	19	16
<i>Test of Basic Scientific Literacy (TBSL)</i>	0.95	4.8	7	110



**Table 4.8.** The intercorrelation ( $r$ ) of scores on the TBSL and its constituent subtests.

Test	NSST	SCKST	ISTSST
SCKST	0.67		
ISTSST	0.62	0.74	
TBSL	0.79	0.98	0.83

A further way to express the reliability of test scores is the standard error of measurement which is an estimate of the degree of imprecision or inconsistency of an individual's scores on hypothetical repeated testing (Berk, 1984c). As individual-specific statistics are computed and interpreted separately for each individual - with the large sample size ( $N = 4227$ ) a clearly impractical condition - a group-specific estimate ( $\sigma(\Delta)$ ) was used instead. This statistic is computed directly from the mean and variance of the observed test scores by the following formula contained in Lord and Novick (1968, p. 251) cited by Berk (1984c):

$$\sigma(\Delta) = \sqrt{\frac{1}{k-1} [\bar{x}(k - \bar{x}) - s^2]}$$

where  $k$  is the number of test-items,  $\bar{x}$  is the mean test score and  $s^2$  is the variance of the test scores. The estimate of the standard error of measurement is an average of the individual-specific errors of measurement and is affected by test length and by the composition of the group tested or the form of the test-score distribution (Berk, 1984c). Although the various subtests of the TBSL consist of a comparatively large number of test-items, the test-score distribution of each subtest was positively skewed (unpublished data). The estimate of the group-specific standard error of measurement should therefore be taken as a comparatively rough approximation of the individual-specific errors or variations reflecting the imprecision of measurement. Estimates of this statistic for the TBSL and its constituent subtests are given in Table 4.7.

It has been reported that reliabilities should ideally not be below 0.8 for widely used tests (Carmines & Zeller, 1979). The reliabilities of the various subtests of the TBSL, and that of the TBSL itself, are either well above 0.8 or close to this value (Table 4.7). Moreover, the standard error of measurement indicates that the test score of individuals will differ from their 'true' score by values of the order of 2.2, 3.8, 1.8, and 4.8 points for the NSST, SCKST, ISTSST, and TBSL, respectively (Table 4.7). Compared to the tests' total score of 22, 72, 16, and 110, respectively, the standard error ranges are thus generally small. The relatively high internal consistency, the comparatively small standard errors of measurement

and hence low measurement coefficients of variation<sup>6</sup> (Table 4.7) of the TBSL and its subtests indicate that the internal reliability of the test scores of the TBSL is sufficiently high to justify the use of this test in the intended manner.

### Reliability of mastery-nonmastery classification decisions

Indices that evaluate the reliability or consistency of mastery-nonmastery classifications over repeated testing of the same group are measures of agreement between categorical data sets based on mastery-nonmastery classifications (Berk, 1984c; Subkoviak, 1984). The index of agreement used for the TBSL was based on a threshold loss function, which assumes that losses related to decision errors are equally serious, regardless of how far the misclassified students are from the cut-off score (Berk, 1984c).

For tests such as the TBSL where an absolute cut-off point is chosen, the use of  $p_o$  as the index of agreement is recommended (Berk, 1984c). This index is the proportion of mastery-nonmastery classification decisions that are in agreement in two test administrations (Berk, 1984c; Hambleton & Rogers, 1991). To calculate  $p_o$ , Peng and Subkoviak's (1980) simple normal approximation of Huynh's (1976) procedure, for which only one test administration is required, was used. The calculation of this index essentially involves the Kuder-Richardson 21 coefficient, the mean and standard deviation of test-score, and the cut-off score. Further details of this method and the calculation of  $p_o$  are given by Subkoviak (1984). The bounds of  $p_o$  are 0 and +1.00, and the upper limit of  $p_o$  occurs only if all individuals are consistently classified (Subkoviak, 1984).

The index of consistency of mastery-nonmastery classification decisions for the overall TBSL was calculated to be 0.84. The index for the three subtests of the TBSL, namely the Nature of Science Subtest, Science Content Knowledge Subtest, and Impact of Science and Technology on Society Subtest, is 0.70, 0.84, and 0.74, respectively. These results show that the consistency of mastery-nonmastery classification decisions based on the TBSL with regard to scientific literacy is comparatively high. Levels of decision consistency between 70% and 90% are generally acceptable for criterion-referenced tests that are used to monitor performance on a day-to-day basis, although a level of decision consistency of over 90% has become the goal for important tests such as, for example, those used for awarding high-school diplomas or licenses to practice in a profession (Hambleton & Rogers, 1991). Factors that can influence the value of  $p_o$  are test length, quality of test-items, choice of cut-off score and group heterogeneity, and the closeness of the group mean performance to the cut-off score (Berk, 1984c; Hambleton & Rogers, 1991). The large group of students to whom this test was administered was not homogeneous: participating students at the five tertiary educational institutions came from a variety of educational and

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6. The measurement coefficient of variation expresses an estimate of the 'true' standard deviation of a subtest score (i.e., the standard error of measurement) as a percentage of the relevant mean subtest score.

socio-economic backgrounds (unpublished data), and were registered for first degrees in commerce and management, in the human and natural sciences, and in engineering. Furthermore, cut-off scores for minimal competency were very close to the group mean performance. Although not sufficiently reliable to be the basis for, for example, national proficiency examinations for scientific literacy, the TBSL is nevertheless a clearly reliable instrument for classifying South African matriculants into categories of minimal scientific literacy and illiteracy.

## CONCLUSION

Through a series of carefully considered steps I have constructed a 110-item *Test of Basic Scientific Literacy*, a paper-and-pencil test instrument based on selected literacy goals recommended by the AAAS in *Science for all Americans* - to my knowledge the only widely accepted document clearly identifying the skills, knowledge, and habits of mind to be attained by high-school leavers in order to be regarded as scientifically literate. The scientific literacy test-items included in the test have been selected on the basis of item discrimination and relevance of content, and possess a substantial degree of content, construct, and item validity, as well as high technical quality. Each of the three subtests comprising the TBSL corresponds to one of Miller's three 'constituent dimensions' of scientific literacy, and the test has been shown to be a reliable instrument for classifying specifically South African matriculants into categories of minimal scientific literacy and illiteracy. The examination of the potential effect of guessing is suggested as a field of further research, but in the light of the probability modelling and empirical evidence provided earlier such analyses were deemed unnecessary in this study. Although the scientific literacy test was not designed to test complex cognitive abilities and is acknowledged to be limited to testing only fundamental aspects of scientific literacy, I nevertheless believe the TBSL to be important for comparatively inexpensive and efficient, large-scale assessments of scientific literacy in a wide range of contexts.

In the next chapter, the administration of the TBSL to a sample of first-time entering students at the five major tertiary educational institutions in the Western Cape is described.





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## Chapter Five

# THE SCIENTIFIC LITERACY SURVEY

### INTRODUCTION

Data on the scientific literacy and background variables of matriculants entering major tertiary educational institutions in the Western Cape were obtained by means of a questionnaire, a copy of which is presented in Appendix G (pp. 309-330). In this chapter, key attributes of the target population are explained, and the student background variables and their coding is detailed. The administration of the survey and the final overall student sample is then described, and finally the representativeness of the sample is assessed.

The Western Cape accommodates approximately 9% of the total population (CSS, 1995) but plays a disproportionally large role compared to its population in the university and technikon sectors. In 1991, the Cape and Peninsula Technikons, and the Universities of Cape Town, Stellenbosch and the Western Cape, accommodated 24% and 23% of South Africa's residential university and technikon students, respectively (File, 1994). The medium of instruction at four of the five institutions is English, but Afrikaans at the fifth (i.e., at the University of Stellenbosch). (Where feasible, however, the Cape Technikon also offers courses in Afrikaans in addition to English.) Each of the three universities and two technikons enrolls the majority of its students at the undergraduate level (File, 1994).

A general aim of this study is to be able to make an assessment of the ability of South African science education to produce scientifically literate matriculants (Chapter 1). It can be argued, therefore, that students should be tested ideally towards the end of the last year of high-school, that is in year 12, or as soon as possible after matriculating. The decision to test students entering tertiary education, as opposed to testing those matriculating, was made both for practical and for conceptual reasons. Firstly, for a number of reasons it is less of a logistic *tour de force* to test South African students at tertiary educational institutions than at a large number of different high-schools. Secondly, and more importantly, matriculants at tertiary educational institutions represent a self-selected group of 'successful' matriculants. It is therefore not unreasonable to believe that this latter group is more likely to exhibit successful outcomes of secondary education, such as, for example, being scientifically literate, than 'less successful' matriculants who do not enter tertiary education.

In order to limit the period in which scientific literacy could be potentially acquired by students after matriculating (i.e., outside of the formal education system), the interval between matriculating and entering tertiary education was minimised in this survey. Only students entering tertiary education for the

first time were therefore selected for the final sample, and students needed to have matriculated within the two preceding years, that is during 1992 or 1993. The latter decision was taken in order not to exclude individuals who had performed military service before entering tertiary education but after matriculating.

Selected students also needed to be younger than 24 years of age. Considering that students should ideally be tested as soon as possible after matriculating, this age cut-off point may appear to be relatively generous. It does, however, reflect the South African educational situation, where significant differences exist in the age distribution of Black (particularly Coloured and African) and White students enrolled in Std. 10 (i.e., year 12) (EduSource, 1994a). Whereas 86% of White students who were in Std. 10 in 1991 fell in the 17-18 year age group, one third of all African students similarly enrolled were 21 years or older (EduSource, 1994a). The age distribution of African students shifted even more in 1993, where 29.7% of students in Std 10 were 22 years or older (Department of Education and Training, unpublished data). In order not to exclude a potentially substantial number of African students from participating in the survey, an age limit of 23 years was chosen.

## THE SURVEY QUESTIONNAIRE

The survey questionnaire consists of two sections (Appendix G, pp. 309-330). Section A sought self-reported retrospective data in a number of different areas: demographic, educational, and socio-economic. Data on the outcome variable - scientific literacy - were provided by the 110-item *Test of Basic Scientific Literacy* (Chapter 4), which formed Section B of the questionnaire. Selected student background variables were largely - but not exclusively - based on and coded similarly to appropriate ones used in the 1987 Longitudinal Study of American Youth (LSAY). LSAY is a U.S. National Science Foundation project focusing on the academic development of middle and high-school students in science and mathematics (Miller, Suchner, Hoffer, & Brown, 1990), and has provided the data for a number of investigations such as, for example, Miller (1995), Reynolds and Walberg (1991, 1992), Reynolds (1991), Pifer (1994, 1995), and Wang and Wildman (1995). The link between certain variables used in the present study and those used in LSAY is indicated by giving the appropriate question number of the Fall 1987 Cohort 1 Questionnaire (i.e., LSAY-AAxx) and the Spring 1989 Teacher Questionnaire (i.e., LSAY-Bxx) (Miller et al., 1990) in parentheses after relevant variables. As LSAY items were administered in this study to students who had already left high-school, the questions were modified where necessary with regard to both style and content in order for the items to be appropriate for my purpose and for the South African context. The questions originating in the Spring 1989 Teacher Questionnaire were modified and addressed to students to obtain the students' retrospective views on

instructional objectives and science class activities. Below, details of the student background variables, as well as the coding used in this study, are provided.

In this study, 53 variables and unobservable variables (i.e., latent constructs) were available for investigating the scientific literacy of matriculants entering the five major tertiary educational institutions in the Western Cape. Characteristics and descriptive statistics of these variables are presented in Table 5.1. It has been suggested that reliabilities should ideally not be below 0.80 for widely used scales (Carmines & Zeller, 1979), and the alpha of the majority of scales was at or close to this value (Table 5.1). Cronbach's alpha, the measure of reliability used here, is not appropriate for single-item scales such as binary variables. The mean of dichotomously scored variables represents the proportion of individuals who scored 1, but the standard deviation of this proportion is not directly interpretable. Due to missing data, sample sizes of cases for the descriptive statistics varied (minimum  $N = 3298$ , maximum  $N = 4227$ ). The characteristics and coding of each variable are now described in turn.

Age and gender are self-explanatory. Until after the elections in April 1994, the examining authorities (i.e., usually departments of education) for South African secondary school-leaving examinations were essentially racially based (Chapter 1). Individual Departments of Education existed for Coloured and Indian students, whereas one existed for White students in each of the then four provinces. There was also a national examining authority, namely the Department of National Education, which offered the National Senior Certificate. The Department of Education and Training was responsible for African students within South Africa, the self-governing homelands, and all the 'independent' homelands except Transkei, which had its own Department of Education (Chapter 1). The Joint Matriculation Board (JMB) controlled certification and examination moderation at a national level. In 1993 it was replaced by the Independent Examinations Board (IEB).

The matric result is a six-point scale ranging from A (80% to 100%) to F (33% to 39%), and relates to the symbol of the overall result of the school-leaving examinations ('matric') at the end of school year 12. The number of science subjects relates to how many science subjects were taken in matric; three is the maximum allowable in terms of the matric regulations. Science subject combination identifies each student's combination of science subjects out of the five Natural Sciences subjects widely taken in senior high-school in South Africa: Agricultural Science, Biology, Geography, Physical Science, and Physiology. Students who also took Mathematics in addition to science subjects in senior high-school were indexed as "yes" or "no". The size of the science class was estimated by each student as an overall average number of students per class for all of the individual student's science subject combination taken together, excluding mathematics. Membership of a science club or science society at school was indexed as "yes" or "no", as was the holding of at least one holiday-job related to science, engineering, medicine, or technology.



**Table 5.1.** Description of variables and latent constructs available in this study for investigating the scientific literacy of matriculants. The reliability ( $\alpha_{20}$ ), mean ( $M$ ), and standard deviation ( $SD$ ) is given for each variable.

No.	Variable/Latent construct	Coding	$\alpha_{20}$	$M$	$SD$
1.	Age	Years	-	19.0	0.9
2.	Gender	0 = Female, 1 = Male	-	0.52	0.50
3.	Examining authority	Dept of National Educ.; 4 provincial Depts of Education for Whites (Cape, Orange Free State, Natal, Transvaal); 1 Dept of Educ. each for Coloureds and Indians; DET and Transkei Educ. Dept for Africans; JMB/IEB	-	-	-
4.	Matric result	6-point scale: A, B, C, D, E, F	-	-	-
5.	Number of science subjects taken in matric	4-point scale: none, 1, 2, 3	-	1.7	0.8
6.	Science subject combination	7 major combinations: Biology, Biology and Physical Science, Biology and Geography, etc.	-	-	-
7.	Mathematics	Whether taken in addition to science subjects: 0 = no, 1 = yes	-	0.85	0.36
8.	Class size	Number of students per science class: one estimated average for student's science subject combination	-	26.2	8.9
9.	Science club member	0 = no, 1 = yes	-	0.13	0.33
10.	Science-related holiday job	0 = no, 1 = yes	-	0.15	0.35
11.	Instructional objectives	10-item composite: e.g. "Increasing student's awareness of importance of science in daily life"; 4-point scale: 1 = almost never, 4 = very often	0.81	24.9	5.2
12.	Science class activities	11-item composite: e.g. "Discuss TV programs about science"; 4-point scale: 1 = almost never, 4 = very often	0.81	24.1	5.5
13.	Open-endedness	7-item composite (SLEI); 5-point scale: 1 = never, 5 = always	0.62	15.6	4.1
14.	Participation	5-item composite (ICEQ); 5-point scale: 1 = never, 5 = always	0.78	19.5	3.8
15.	Personalisation	5-item composite (ICEQ); 5-point scale: 1 = never, 5 = always	0.81	19.2	4.0
16.	Rule clarity	4-item composite (CES); 5-point scale: 1 = never, 5 = always	0.67	13.7	3.3
17.	Classroom environment	Aggregate of 13-16	0.82	68.1	10.5
18.	Instructional quality	Aggregate of 11, 12, and 17	0.91	117.2	18.4
19.	Homework for all science subjects	Hours per week	-	4.9	4.1
20.	Interest in science	3-item composite: e.g. "I enjoy science"; 5-point scale: 1 = strongly agree, 5 = strongly disagree	0.77	10.6	2.5
21.	Perceived usefulness of science	4-item composite: e.g. "Science helps a person think logically"; 5-point scale: 1 = strongly agree, 5 = strongly disagree	0.70	14.6	2.9

Table 5.1 continued

No.	Variable/Latent construct	Coding	$\alpha_{20}$	<i>M</i>	<i>SD</i>
22.	Attitude toward science	Aggregate of 20 and 21	0.80	25.2	4.7
23.	Persistence	2-item composite: e.g. "I tried hard to do my best at school"; 5-point scale: 1 = never, 5 = always	0.73	8.4	1.6
24.	Intrinsic motivation	3-item composite: e.g. "I day-dreamed at school"; 5-point scale: 1 = always, 5 = never	0.72	8.8	2.7
25.	Motivation	Aggregate of 23 and 24	0.78	17.3	3.7
<i>Most of my friends:</i>					
26.	Liked science at school	0 = no, 1 = yes	-	0.41	0.49
27.	Did well at science in school	0 = no, 1 = yes	-	0.39	0.49
28.	Were really good students in school	0 = no, 1 = yes	-	0.54	0.50
29.	Hope to become scientists, doctors or engineers	0 = no, 1 = yes	-	0.39	0.49
30.	Go to university, technikon, or college	0 = no, 1 = yes	-	0.86	0.35
31.	Watch a lot of TV	0 = yes, 1 = no	-	0.47	0.50
32.	Peer environment	Aggregate of 26-31	-	3.1	1.5
33.	Exposure to TV in general	Number of hours spent watching TV per week	-	9.7	8.1
Exposure to science-related media:					
34.	Print media	At least once per month: Read article in science magazine or book, and science-related articles in newspaper or women's magazine; 0 = no, 1 = yes	-	0.79	0.41
35.	Broadcast media: TV	Watched a science-related program on TV; 0 = no, 1 = yes	-	0.80	0.40
36.	Broadcast media: radio	Listened to science-related program on radio; 0 = no, 1 = yes	-	0.21	0.41
37.	Home language	Afrikaans, English, English & Afrikaans, Ndebele, Northern/Southern Sotho, Swazi, Tsonga, Tswana, Venda, Xhosa, Zulu	-	-	-
38.	Population group	Derived from Examining authority and Home language: African, Coloured, Indian, White	-	-	-
39.	Family size	Number of siblings	-	2.3	1.5
40.	Family structure	4-point scale: Living with 1 = intact two-parent family, 2 = mother only, 3 = father only, 4 = relative	-	1.1	0.8
41.	Parents' highest educational attainment	5-point scale: 1 = less than primary school, 5 = university	-	3.8	1.1
42.	Science-related occupation of parents	Occupation related to science, engineering, medicine, or technology; 0 = neither parent, 1 = one parent, 2 = both parents	-	0.6	0.7

Table 5.1 continued

No.	Variable/Latent construct	Coding	$\alpha_{20}$	<i>M</i>	<i>SD</i>
43.	Parental encouragement	6-item composite: e.g. My parents "expected me to do well in science at school", "think that science is a very important subject"	-	2.9	1.5
44.	Parental involvement	7-item composite: list of six cultural venues visited together with parents (e.g., museum, planetarium, zoo, etc.), and "my parents really enjoy doing things with me"	-	2.5	1.8
45.	Specific place to study	0 = no, 1 = yes	-	0.82	0.38
46.	Own bedroom	0 = no, 1 = yes	-	0.82	0.38
47.	Daily newspaper	0 = no, 1 = yes	-	0.66	0.47
48.	Weekly news magazine (e.g., "Newsweek", etc.)	0 = no, 1 = yes	-	0.43	0.49
49.	Science magazine (e.g., "National Geographic", "New Scientist", etc.)	0 = no, 1 = yes	-	0.21	0.41
50.	Atlas or globe	0 = no, 1 = yes	-	0.62	0.49
51.	Personal computer	0 = no, 1 = yes	-	0.39	0.49
52.	Pocket calculator	0 = no, 1 = yes	-	0.95	0.22
53.	Number of books available at home	5-point scale: 1 = fewer than 50, 5 = more than 500	-	3.0	1.3

Instructional quality was measured by the aggregate of instructional objectives, science class activities, and classroom environment. Instructional objectives were indicated by 10 items on the science teacher's instructional objectives (e.g., "increasing students' interest in science", "teaching students how to design experiments", and "teaching about applications of science to environmental issues") (LSAY-B18). Science class activities were indicated by 11 items on the frequency of particular science activities (e.g. "write reports on experiments or systematic observations", "discuss current magazine articles or books related to science", and "discuss career opportunities in scientific or technological fields") (LSAY-B19).

Classroom environment was measured by a composite indicator of 21 items derived from short forms of the following assessment instruments of students' perceptions of actual psycho-social classroom environments: *Science Laboratory Environment Inventory* (SLEI) (Fraser, Giddings, & McRobbie, 1991, 1992), *Individualized Classroom Environment Questionnaire* (ICEQ), and *Classroom Environment Scale* (CES) (Fraser & Fisher, 1986). These assessment instruments consist of a number of different scales, of which the following were regarded as salient for this study: (a) open-endedness (seven items taken from SLEI) - measuring the extent to which laboratory activities emphasise an open-ended, divergent approach to experimentation (Fraser et al., 1992); (b) rule clarity (four items taken from CES) - measuring the extent to which behaviour in the classroom is guided by formal rules (Fraser et al.,

1992); (c) participation (five items taken from ICEQ) - measuring the extent to which students are encouraged to participate, rather than be passive listeners (Fraser, 1990); and (d) personalisation (five items taken from ICEQ) - measuring the extent to which the emphasis in the classroom is, firstly, on opportunities for individual students to interact with the teacher and, secondly, on the teacher's concern for personal welfare and social growth of the individual (Fraser, 1990). Each of the above assessment instruments of classroom environment has an actual (i.e., real) and a preferred (i.e., ideal) form. All items used here are from the actual form. The wording of all items was modified to be appropriate for the retrospective nature of this study.

The above four classroom environment scales were selected for the following two reasons. Firstly, they provide the necessary coverage of the three general categories of dimensions that must, according to Moos (1974; cited in Fraser et al., 1992), be assessed in order to provide an adequate and reasonably complete picture of any human environment. These categories are the Relationship Dimensions (i.e., personalisation, participation), Personal Development Dimensions (i.e., open-endedness), and Systems Maintenance and System Change Dimensions (i.e., rule clarity). Secondly, the selected dimensions were perceived to be of importance to learning and thus to scientific literacy in general. The scales of open-endedness of laboratory sessions, personalisation, and participation all represent opportunities for students to actively engage with the subject matter and in this manner to construct meaning for themselves. Rule clarity was regarded as a rough indicator of classroom management skills and thus of teacher effectiveness (see, for example, Cohn & Rossmiller, 1987).

Instructional quantity was measured by student homework in science subjects (not more than three subjects, excluding Mathematics), and was indexed by the number of hours spent on this activity per week. Any report of more than 23 hours of science homework per week was from experience believed to be beyond reasonable expectations for the majority of adolescents and thus highly unlikely. Twenty-three hours of science homework per week was therefore taken as the theoretical maximum for this variable. Attitude towards science was indexed by a composite of two scales: interest and usefulness (LSAY-AA39). Interest in science was the aggregate of three items ("I enjoy science", "I am good at science", and "I usually understood what we did in science"). Usefulness was indexed by four items ("Science is useful in everyday problems", "Science helps a person think logically", "It is important to know science to get a good job", and "I will use science in many different ways as an adult"). Motivation was measured by a two-item persistence scale ("I tried hard to do my best at school" and "I tried harder if I obtained bad marks"), and a three-item intrinsic motivation scale ("I day-dreamed at school", "I waited to the last minute before studying", and "I would rather be doing things other than studying") (LSAY-AA38).

Peer environment was indexed by six variables: six statements ("Most of my friends: a) liked science at school; b) did well in science at school; c) were really good students at school; d) hope to become scientists, doctors or engineers; e) go to university, technikon or college; and f) watch a lot of TV") to

which students had to reply affirmatively if the described situations applied to them (LSAY-AA20). Exposure to mass media in general was measured by the number of hours per week students spent watching TV. Any report of more than 42 hours per week - an average of six hours per day - was believed to be beyond reasonable expectations for the majority of adolescents and thus highly unlikely. Forty-two hours per week was therefore taken as the theoretical maximum for the weekly amount of television viewing. Exposure to science in the print media was indexed by whether students read a science magazine or book, and science-related articles in newspapers or women's magazines at least once a month. Exposure to science on television or radio was indexed by whether students watched or listened to a science-related programme on TV or radio at least once a month.

Variables related to home environment were numerous, in keeping with the documented importance of this factor for educational outcomes in general, and for science achievement in particular (e.g., Kremer & Walberg, 1981; Marjoribanks, 1994; Peng & Wright, 1994; Reynolds & Lee, 1991; Reynolds & Walberg, 1992). However, in the South African context and its legacy of apartheid, population group is likely to play an important role in determining the home environment of matriculants (see, for example, Chapter 6). It was thought inappropriate to directly ask students to state their population group. The nine Black languages spoken in South Africa (Ndebele, Northern/Southern Sotho, Swazi, Tsonga, Tswana, Venda, Xhosa, and Zulu) (Krige, Dove, Makalima, & Scott, 1994) were therefore used together with the formerly racially-based examining authorities to derive the population group of students. This approach was considered to be reliable except in cases of African students whose home language is English and who attend schools under the control of examining authorities other than DET and the Transkei Department of Education. Experience of the current school situation in the Western Cape leads one to conclude that the number of such cases is exceptionally small, and that such possible misclassifications do not significantly influence the results of this survey.

Family size was indicated by the number of siblings students had. Family structure was indexed by whether students lived with both parents, with either mother or father, or with a relative. Parents' educational attainment was indexed by the higher of the mother's or father's completed level of education: less than primary school, primary school, high-school, a technikon or a university qualification. Whether students' parents had an occupation that was directly related to science, engineering, medicine, or technology was indexed by whether neither, one, or both parents had such an occupation. Parental encouragement was the sum of six items ("My parents: a) insisted I do my school homework; b) expected me to do well in science at school; c) think that science is a very important subject; d) would like me to have a career in science, medicine, or engineering; e) always encouraged me to go to a university, technikon, or college; f) know a lot about science") (LSAY-AA19). Parental involvement was the sum of seven items: six items listing the cultural venues the students visited together with their parents at least once in the last two years (i.e., a museum, planetarium, zoo, botanical garden,

art museum, and art gallery) (LSAY-AA28D), as well as an indication of whether “my parents really enjoy doing things with me” (yes or no).

Academic home resources were indexed by eight variables: eight statements to which students had to indicate whether or not their home contained the mentioned resource (“a specific place to do your homework or to study”, “a bedroom of your own”, “a daily newspaper”, “a weekly news magazine, e.g. *Newsweek* or *Time*”, “a science magazine, e.g. *National Geographic* or *New Scientist*”, “an atlas or a globe”, “a PC”, and “a pocket calculator”). The estimated number of books available in the students’ home was indexed on a five-point scale ranging from “fewer than 50” to “more than 500”.

The variables described above comprise all the variables from which further explanatory variables for scientific literacy were constructed. Any deviation from the above coding is described in those chapters which deal with analyses of the survey data.

## THE SURVEY ADMINISTRATION

At the beginning of the 1994 academic year, the survey questionnaire was administered - with a small number of exceptions, always under my supervision - to first-year students at the Cape and Peninsula Technikons, and at the Universities of Cape Town, Stellenbosch and the Western Cape. All students were registered for a bachelor’s degree or National Diploma at the universities and technikons, respectively. The questionnaires were administered to seated students during a normal 45-minute lecture period in a standard manner. In an introduction to students in the presence of their normal lecturer, the general purpose of the scientific literacy survey and the structure of the questionnaire was explained, and the importance of using the “Don’t know” option when appropriate was stressed. Finally, all students were urged to consult me on all questions that were unclear to them, and to complete the questionnaire as best as they could. I was present throughout the 45-minute period.

The survey questionnaires were administered to students registered in 31 first-year courses in disciplines broadly divided into areas of specialisation related to engineering, natural sciences,<sup>1</sup> commerce and management, and the human sciences, using the categories of File (1994). Table 5.2 gives an overview of the disciplines (i.e., Faculties and Schools) sampled per university and technikon. Corresponding broad areas of subject specialisation are also given in this table. At each of the five institutions, disciplines were selected in decreasing order of each discipline’s relative numerical contribution to that institution’s overall first-time entering student population in 1993, until approximately 70% to 80% of the institution’s overall first-time entering student population was accounted for. First-year courses in each discipline were in turn selected on the basis of being considered

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1. The natural sciences include both the life and the physical sciences.

to be representative of each discipline's first-time entering student population with respect to gender and population group. Criteria for each course's appropriateness for selection were based on 1993 student data provided by each institution, as well as on the advice of respective deans and experienced student advisors. Due to administrative and logistic problems beyond my control, the intended student population in the School of Electrical & Mechanical and Computer Data Processing at the Peninsula Technikon was not sampled. Similarly, the intended student population in the Faculty of Economic and Management Sciences at the University of the Western Cape was inadequately sampled.

**Table 5.2.** An overview of the Faculties (universities) and Schools (technikons) sampled per institution and the corresponding broad areas of specialisation according to the categories of File (1994). Faculties and Schools are listed in decreasing order of each Faculty's or School's relative numerical contribution to each institution's overall first-time entering student population in 1994.

Faculty or School sampled	Human Sciences	Comm. & Mngmnt	Natural Sciences	Engineering
<b>Cape Technikon</b>				
Management		X		
Business Informatics		X		
Life Sciences			X	
Electrical Engineering				X
Physical Sciences			X	
Civil Engineering				X
Mechanical Engineering				X
<b>Peninsula Technikon</b>				
Business Studies		X		
Science*			X	
Architecture, Building and Civil Engineering				X
<b>University of Cape Town</b>				
Social Sciences and Humanities	X			
Commerce		X		
Engineering				X
Science			X	
Arts	X			
<b>University of Stellenbosch</b>				
Commerce and Administration		X		
Arts	X			
Natural Sciences			X	
Medicine			X	
Engineering				X
<b>University of the Western Cape</b>				
Arts	X			
Economic and Management Sciences		X		
Science			X	

\* Includes chemical engineering students.

## THE FINAL OVERALL SAMPLE

The scientific literacy survey questionnaire was administered to a total of 6801 students at the three universities and two technikons. Due to a slight, unavoidable overlap of courses in which testing took place, 179 students reported that they had completed the questionnaire before and these students' second data records were therefore excluded from the data set. In the capture and preliminary analysis of the data records, a carefully devised routine was diligently adhered to. All questionnaires were checked for legibility of responses and to ensure that the questionnaire had been completed correctly. In checking, particular attention was paid to detect obvious patterns in the responses to the test-items in the TBSL (such as, for example, a series of consecutive answers of "true", "false", "don't know" or of "true", "false", etc.) which indicated that individuals had not taken the survey seriously. Such questionnaires were considered spoilt, and a total of 331 such student records were excluded from the data set. The remaining 6291 records were captured by a professional data capture service. The accurate capture of responses was verified by capturing all data records a second time, and then electronically comparing the two data sets for inconsistencies. Frequency tables for all variables were then computed, and the data set was 'cleaned' using these tables. The frequency tables allowed the identification of aberrant responses for each variable, upon which the relevant original questionnaire was consulted and the responses modified or deleted from the data set where appropriate.

Of the 6291 student records, 1842 were excluded from further analyses because the records either contained missing age or matriculation-year data, or because students did not fit the target population profile, that is those students who were older than 23 years of age, had matriculated earlier than in 1992, did not enter tertiary education for the first time, or had completed their secondary education outside South Africa. In order to increase the likelihood that only students who could genuinely not complete the 110-item TBSL in the allotted 45 minutes were included in the final data set, it was thought reasonable to establish a maximum for the number of unanswered TBSL test-items allowed per student. Preliminary analyses revealed that of the remaining 4449 students, 74.9% had answered *all* TBSL items, and that 95% had left fewer than 39 test-items unanswered. A maximum number of 38 unanswered TBSL test-items was therefore allowed per student, resulting in the elimination of a further 222 student records. The total sample on which the analyses in the following chapters are based is therefore 4227 student records.

### Sample description

The final sample of 4227 selected students represents 27.9% of *all* registered first-time entering students at the five institutions during 1994, and 34.1% of first-time entering students registered in the natural



sciences and engineering faculties. The actual proportion of the latter category of students of the total number of first-time entering students at all five institutions (i.e., 15 142) is 33.3%. With only 15.7% of students matriculating in 1992, the vast majority of students included in the final sample matriculated in the year prior to entering tertiary education for the first time (i.e., 1993). Students from the University of Stellenbosch (US) formed the greatest proportion of the sample, followed by students from the Cape Technikon (CT), the University of Cape Town (UCT), and the University of the Western Cape (UWC) (Table 5.3). Students from the Peninsula Technikon (PT) formed the smallest proportion of the sample (Table 5.3).

**Table 5.3.** The number of students per area of subject specialisation as a proportion (%) of the sample of each institution, as well as of the overall sample. The proportion (%) of the overall sample formed by each institution is also given.

Area of specialisation	CT	PT	UCT	US	UWC	Overall
Human Sciences	–	–	22.6	27.1	37.3	17.7
Commerce & Management	51.5	57.9	37.1	38.0	4.4	38.9
Natural Sciences	25.4	29.1	26.1	23.3	43.2	27.6
Engineering	23.1	13.0	13.6	9.5	N/A	13.2
Other areas	0	0	0.6	2.1	15.1	2.6
Sample size	1127	392	955	1209	544	4227
Proportion of sample (%)	26.7	9.3	22.6	28.6	12.8	100

Overall, the majority of students were registered for courses in Commerce and Management (38.9%), while 17.7%, 27.6%, 13.2% of students were registered for courses in the Human Sciences, Natural Sciences, and Engineering, respectively (Table 5.3). Only 2.6% of the sample did not fall in any of the above broad areas of subject specialisation (Table 5.3). Due to the manner in which the sample was obtained (see above), the main areas of subject specialisation were not sampled in equal proportions at every institution (Table 5.3). For example, students in Commerce and Management formed 57.9% of the Peninsula Technikon sample, but constituted only 4.4% of the sample in the case of the University of the Western Cape. This contrast means that the institutions' relative contributions to the student sample of each subject specialisation were not equal but variable. These differences in the samples will become relevant to the observed trends of scientific literacy which are discussed in Chapter 6.

African, Coloured, Indian, and White students comprised 14.1%, 25.8%, 1.6%, and 58.5% of the sample, respectively; 41.5% of students were Black (Table 5.4). Due to the manner in which the sample was obtained (see above), the overall sample does not consist of equal proportions of students of different population groups in the four areas of subject specialisation. For example, 16.2% of White students fell into the area of Engineering, whereas only 5.9% of African students fell into this subject specialisation

(Table 5.4). Again, these differences in the sample will become relevant to the observed trends of scientific literacy which are discussed in Chapter 6.

Overall, 51.7% of the sample was male. Male/female ratios were approximately equal for the Universities of Cape Town and Stellenbosch and the Peninsula Technikon. However, at the Cape Technikon and the University of the Western Cape males and females represented roughly two thirds of students, respectively.

**Table 5.4.** The relative proportion (%) of students in the main areas of subject specialisation within the sample of each population group.

Area of specialisation	African	Coloured	Indian	White	Total no. of students
Human Sciences	36.6	15.7	10.5	14.2	747
Commerce & Management	24.7	35.4	29.8	44.1	1642
Natural Sciences	27.2	34.9	38.8	24.2	1166
Engineering	5.9	10.0	16.4	16.2	555
Other	5.6	4.0	4.5	1.3	113
Sample size	595	1091	67	2470	4223 <sup>2</sup>
Proportion of sample (%)	14.1	25.8	1.6	58.5	100

### Sample representativeness

In order to be able to make defensible generalisations about the scientific literacy of first-time entering students based on results obtained from the present survey, it is necessary to establish the representativeness of the overall sample with respect to broad areas of subject specialisation, population group, and gender. Moreover, as it may be desirable to be able to draw conclusions about the scientific literacy of students at particular tertiary institutions, it is also necessary to establish the representativeness of the student sample from individual institutions with respect to the above three variables. The representativeness of the sample at both levels of interest is discussed below.

Data of first-time entering students per area of subject specialisation with respect to population group and gender were obtained from each institution after the annual statutory 'headcount' had been carried out in March and June 1994 at technikons and universities respectively. From these data, student

2. The difference between this total and that in Table 5.3 is due to four students whose population group is unidentified. This discrepancy was discovered only after a substantial portion of the data had been analysed. As the discrepancy is very small and therefore unlikely to influence the results in any material way, and as the four students were in any case excluded from all analyses involving population group as a variable, the discrepancy was not corrected.

numbers for appropriate target groups (i.e., all first-time entering students in relevant disciplines) were determined. In each case, the representativeness of the sample was ascertained by comparing the sample with the target group by means of a chi-square test. A statistically significant chi-square value ( $\alpha = 0.05$ ) was taken to indicate evidence of bias or unrepresentativeness of some sort.

### *Overall representativeness*

Overall, there was a statistically significant difference between the composition of target and sample groups with respect to the relative frequency of students in particular areas of specialisation ( $\chi^2 = 214.3$ , d.f. = 3,  $p < 0.00001$ ). Compared with the target group, a lower and higher proportion respectively of students in the Human Sciences and in the Natural Sciences was present in the sample (Table 5.5). The proportion of students in Engineering in the sample group was slightly higher than in the target group, whereas the proportion of students in the sample in Commerce and Management was comparable to that of the target group (Table 5.5).

**Table 5.5.** Frequencies and relative proportions of students in the four major areas of subject specialisation for the target group and overall sample.

	Human Sciences	Comm. & Mngmnt	Natural Sciences	Engineer- ing	Total no. of students
Target group	3456 (27.5%)	5156 (41.1%)	2561 (20.4%)	1373 (10.9%)	12548
Sample group	747 (18.2%)	1644 (40.0%)	1166 (28.3%)	557 (13.5%)	4114

No information other than Black/White distinctions was recorded by the Cape Technikon during the year of sampling. Hence no exact overall comparison of the total sample to target groups with respect to population group or gender was possible. In general, there are statistically significant differences in the population group composition between the sample and actual target groups ( $\chi^2 = 692.6$ , d.f. = 1,  $p < 0.00001$ ), Black and White students being respectively under- and over-represented in the sample (Table 5.6). For students at the Peninsula Technikon and the three universities, both an excess of White students and a relative lack of mainly African students in the sample group accounts for this pattern (Table 5.7). Limited sampling at the Peninsula Technikon and the University of the Western Cape which are historically Black (i.e., they initially admitted mainly Coloured and in recent years increasingly African students) largely accounts for the fact that the total sample of 4227 students is unrepresentative with respect to population group.

Based on data excluding the Cape Technikon, the overall sample is, nevertheless, representative of the first-time entering student population with respect to gender (Table 5.8), as there is no statistically significant difference in the proportion of male and female students between the sample and target groups ( $\chi^2 = 0.509$ , d.f. = 1,  $p > 0.05$ ).

**Table 5.6.** Frequencies and relative proportions of Black and White students in the target and sample groups.

	Black	White	Total no. of students
Target group	7947 (63.3%)	4601 (36.7%)	12548
Sample group	1753 (41.5%)	2470 (58.4%)	4223

**Table 5.7.** Frequencies and relative proportions of African, Coloured, Indian, and White students in the target and sample groups for students in selected courses. Data for the Cape Technikon were excluded (see text).

	African	Coloured	Indian	White	Total no. of students
Target group	3659 (36.6%)	2998 (29.8%)	340 (3.4%)	3071 (30.5%)	10068
Sample group	567 (18.3%)	828 (26.7%)	56 (1.8%)	1647 (53.2%)	3098

**Table 5.8.** Frequencies and relative proportions of male and female students in the target and sample groups. Data for the Cape Technikon were excluded (see text).

	Male	Female	Total no. of students
Target group	4922 (48.9%)	5144 (51.1%)	10066
Sample group	1491 (48.1%)	1606 (51.9%)	3097

*Representativeness of sample at the level of institutions*

The relative proportion of students in different areas of subject specialisation in the sample group approximated in only a few instances to the relative proportion of students in the target group (Table 5.9). Although differences in proportions of students in the above two groups were statistically significantly different for all institutions, the student sample approximated the target group better at some institutions than at others (Table 5.9). For example, the relative proportion of students in the four areas of subject specialisation appeared to be relatively well matched to the target group at the University of Stellenbosch, and to a lesser extent at the Cape Technikon (Table 5.9). However, the sample at the University of the Western Cape, and to a lesser extent at the University of Cape Town and at the Peninsula Technikon, favoured students in the Natural Sciences (Table 5.9).

**Table 5.9.** Comparison of the relative proportion (%) of the number of students per area of subject specialisation in the target and sample group at different institutions. For each institution, the difference in the student composition between the target and sample group with respect to areas of subject specialisation is statistically significant (chi-square test,  $p < 0.05$ ).

	Human Sciences	Comm. & Mngmnt	Natural Sciences	Engineer- ing	Total no. of students
<b>Cape Technikon</b>					
Target group	N/A	57.7	19.3	23.1	2480
Sample group	N/A	51.5	25.4	23.1	1127
<b>Peninsula Technikon</b>					
Target group	N/A	71.1	20.7	8.2	2470
Sample group	N/A	57.9	29.1	13.0	392
<b>Univ. of Cape Town</b>					
Target group	41.0	24.4	16.9	17.6	2081
Sample group	22.8	37.3	26.2	13.7	949
<b>Univ. of Stellenbosch</b>					
Target group	28.4	32.4	29.5	9.7	2402
Sample group	27.7	38.8	23.8	9.7	1187
<b>Univ. of the Western Cape</b>					
Target group	61.7	21.9	16.9	N/A	3115
Sample group	43.9	5.2	50.9	N/A	462

The overall student sample at institutions other than the University of Stellenbosch was unrepresentative with respect to population group (Table 5.10). Whereas at the Peninsula Technikon and at the University of the Western Cape this unrepresentativeness is due to an under-representation of African students, the unrepresentativeness of the sample at the University of Cape Town is largely due to

an over-representation of White students (unpublished data). With very few exceptions, the student sample at the level of subject specialisation for different institutions was also unrepresentative with respect to population group (Table 5.10). The absence of relevant data for the Cape Technikon made the identification of the over- or under-representation of a particular population group impossible, but Black/White distinctions could nevertheless be made. With the exception of the University of the Western Cape, where female students were over-represented (unpublished data), the student sample at every institution is representative with respect to gender (Table 5.10).

In summary, the overall sample is not representative with respect to areas of subject specialisation of the first-time entering student population at the five major tertiary educational institutions in the Western Cape, and the total sample slightly favours students in the Natural Sciences and Engineering at the expense of those in the Human Sciences. Furthermore, the overall sample is also not representative of the total first-time entering student population with respect to population group, as African students are under-represented in the sample. The overall sample is, however, representative of the target group with respect to gender.

The student sample from each individual tertiary educational institution was not representative of each institution's first-time entering student population with respect to area of subject specialisation and population group, but was representative with respect to gender except at the University of the Western Cape. In general, the student sample from the University of Stellenbosch best matched the profile of its first-time entering student group. Its relatively heterogeneous student population, and the exemplary co-operation received from this institution in the design of the sampling procedure and in the administration of the *Test of Basic Scientific Literacy* is likely to have contributed considerably to the representative selection of this sample.

Although the random, representative selection of a sample is always the goal or ideal, such selection in surveys in the social sciences is generally limited by cost and time constraints related to accessibility of the subjects (i.e., students). Gaining access to tertiary education students in a variety of different faculties during jealously guarded lectures is generally a sensitive issue, particularly in a climate where research on such students is not necessarily seen as being of a high priority. Given these constraints, it is extraordinarily difficult to attain proportions of students from different population groups in the different areas of subject specialisation that accurately reflect the actual proportion of the first-time entering student population at the various institutions, despite the meticulous care that was taken with the sampling procedure. Although statistical techniques such as, for example, the chi-square test, detect unrepresentativeness, it is an accepted statistical fact that *any* deviation from non-conformity between sample and ideal figures will be statistically significant if the sample size is large enough. Given the comparatively large sample sizes obtained in this survey (Tables 5.3 and 5.4), it is therefore not

surprising that the chi-square test used to establish representativeness detected statistically significant differences between the sample and the target group in virtually all instances.

**Table 5.10.** A summary of comparisons of the final sample with the target population with respect to gender and population group at the overall level and at the level of subject specialisation for different tertiary educational institutions. A statistically significant and not significant chi-square test is indicated by a “✓” and a “x”, respectively ( $\alpha = 0.05$ ).

Institution	Gender	Population group
<b>Cape Technikon<sup>a</sup></b>		
Overall	–	✓
Human Sciences	N/A	N/A
Commerce & Management	–	✓
Natural Sciences	–	✓
Engineering	–	✓
<b>Peninsula Technikon</b>		
Overall	x	✓
Human Sciences	N/A	N/A
Commerce & Management		✓
Natural Sciences <sup>b</sup>		✓
Engineering <sup>c</sup>		x
<b>University of Cape Town</b>		
Overall	x	✓
Human Sciences		x
Commerce & Management		✓
Natural Sciences		✓
Engineering		✓
<b>University of Stellenbosch</b>		
Overall	x	x
Human Sciences		x
Commerce & Management		x
Natural Sciences		x
Engineering		x
<b>University of the Western Cape</b>		
Overall	✓	✓
Human Sciences		✓
Commerce & Management		x
Natural Sciences		✓
Engineering	N/A	N/A

*Note.*

<sup>a</sup> No population group information other than Black/White distinctions was recorded by the Cape Technikon for first-time entering students. Data on gender were not available.

<sup>b</sup> Chemical engineering students are included under Natural Sciences, as they were registered in the School of Sciences but were not identifiable in the target population.

<sup>c</sup> Chemical engineering students are not included (see above).

The meaningfulness of such statistically significant differences, however, needs to be decided in additional contexts apart from that of statistics, as statistically significant differences do not necessarily translate into, for example, *educationally* significant distinctions in inference, decision-making, or practices. In the present survey, sample sizes for students in most population groups and different areas of subject specialisation are substantial (Table 5.4). Thus, despite the fact that the obtained sample is unrepresentative in a number of ways, important insights into the scientific literacy of first-time entering students in the Western Cape can be obtained from the procured sample of African, Coloured, Indian, and White students, as well as from the sample of students in the four major areas of subject specialisation. The lower, but still substantial, sample of African students in comparison with that of Coloured and White students means that conclusions based on the sample of African students will be less precise and therefore more tentative than the conclusions based on the sample of the latter group of students. The small sample size of Indian students necessarily makes any conclusions based on this sample even more tentative, but in the absence of any other data such conclusions are nevertheless of interest. The comparatively low sample size of African, and particularly Indian, students provides directions for future surveys of scientific literacy of South African matriculants.

## CONCLUSION

In a carefully planned procedure, the student target population for this scientific literacy survey was first identified and then sampled. Due to the diligence and meticulousness with which the data set was captured, verified and cleaned, I am confident that the student records accurately reflect the responses given by students to questions in the survey questionnaire, and that the profile of students included in the final data set adequately approximates that of the desired target population with respect to the major relevant variables.

Based on the final sample of 4227 students described above, the level of scientific literacy of first-time entering students at the five major tertiary educational institutions in the Western Cape is described, and multivariate logistic regression models of predictors of scientifically literate students are developed. These features of the scientific literacy of Western Cape matriculants are the subject of the following two chapters.





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## Chapter Six

# LEVELS OF SCIENTIFIC LITERACY OF MATRICULANTS ENTERING MAJOR TERTIARY EDUCATIONAL INSTITUTIONS IN THE WESTERN CAPE

## INTRODUCTION

In an increasingly science-based and technological world, it is now widely accepted that a minimal understanding of science has become a prerequisite for effective citizenship (Chapter 2). Furthermore, there is growing recognition in the industrialised world that scientific literacy is a crucial component of long-term economic growth (e.g., Bloch, 1986; Hurd, 1989; Walberg, 1983). South Africa is currently facing a challenging future but there appears to be little doubt that the development of a scientifically literate citizenry is a *sine qua non* for South Africa's economic prosperity and social progress (Chapter 1).

Various national and cross-national surveys have shown that a large proportion of adults in the United States (e.g., Miller et al., 1980; Miller, 1987, 1989b) and Britain (e.g., Durant et al., 1989; Lucas, 1987ab, 1988) has a very limited knowledge and understanding of science. In contrast to other countries, a survey of the scientific literacy of a representative sample of the South African adult public has yet to be undertaken (Chapter 1). However, a limited study conducted amongst White adults provided some evidence that South Africans performed similarly to Americans and Britons on questions related to physics and the earth sciences (Pouris, 1991b). In general, these national and cross-national surveys have shown that an individual's understanding of the various dimensions of scientific literacy (Chapter 2) is influenced by a number of factors, including age, gender, and social class (e.g., Durant et al., 1989). However, the most important factor associated with scientific literacy was consistently shown to be education (e.g., BIE, 1995; Durant et al., 1989; NSB, 1989, 1991, 1993).

With the exception of Glover (1992) and Pouris (1993), published research on the relationship between education and scientific literacy in South Africa has been limited exclusively to investigating the promotion of scientific literacy of secondary school pupils through informal, as opposed to non-formal or formal, science teaching (Chapter 1). In the - to the best of my knowledge - only South African investigation of scientific literacy with respect to formal education, Glover (1992) examined the performance of science teachers in Ciskei and Transkei (former 'independent' African homelands) with reference to strategies appropriate to the development of scientific literacy. Pouris (1993) conducted a scientific literacy survey amongst a cross-section of South African teenagers in which he reported inter

alia that White teenagers perform better than White adults, but the survey was not specifically related to any aspect of formal education. In South Africa, there is thus a comparative lack of data with regard to scientific literacy and variables related to formal education.

In the last decade or so, education in South Africa in general has increasingly come under the spotlight in order to examine appropriate education policy alternatives to the racially-discriminatory education system in place (Chapter 1), especially since it became obvious from former President De Klerk's speech in February 1990 that the removal of the National Party from government was highly likely. The National Education Policy Investigation, for example, constitutes a major enquiry into the policy options for a future education dispensation for South Africa, and has made a number of important policy proposals (NEPI, 1993). Given the perceived need for scientifically literate individuals in South Africa (Chapter 1), and given the paucity of relevant data with respect to associations between scientific literacy and formal education in South Africa, it is highly relevant to attempt to assess, and to provide baseline data on, the ability of the science education provided by the recent education system to generate scientifically literate matriculants. This assessment should ideally be carried out before new education policies (as discussed, for example, in the *White Paper on Education and Training* [RSA, 1995]) are implemented, so that the impact of the new policies can be gauged. For the purpose of assessment, it was thought appropriate to examine the scientific literacy of what can be regarded as the 'products' of the current education system, that is school-leavers with a matriculation pass (i.e., matriculants). For practical and conceptual reasons (Chapter 5), the investigation was limited to matriculants at the secondary/tertiary education interface in the Western Cape.

In this chapter, the scientific literacy of first-time entering students of different population groups in various broad areas of subject specialisation is analysed. Levels of scientific literacy are examined with respect to a number of student background variables, as well as with respect to variables related to secondary and tertiary education. The methodology of this study is outlined first, with patterns of scientific literacy described thereafter.

## METHODOLOGY

This study was based on a survey of 4227 first-year students at the five major tertiary educational institutions in the Western Cape: the Cape and Peninsula Technikons, and the Universities of Cape Town, Stellenbosch and the Western Cape (Chapter 5). This sample of students represents 27.9% of *all* registered first-time entering students at the five institutions during 1994, and 34.1% of first-time entering students registered in the natural sciences and engineering faculties (Chapter 5). The proportion of the latter category of students in the sample is virtually identical to the actual proportion these students

comprise of the total number of first-time entering students at all five institutions (Chapter 5). Section A of the survey questionnaire (Appendix G, pp. 309-330) sought self-reported data in a number of different areas (i.e., demographic, educational, socio-economic), and student responses to questions relating to variables in these areas (see Chapter 5, Table 5.1, pp. 90-92) are used in this study. Students were classified as scientifically literate on the basis of completing the 110-item *Test of Basic Scientific Literacy* (Chapter 4), which formed Section B of the survey questionnaire (Appendix G).

By 'level' of scientific literacy is meant the proportion (i.e., percentage) of scientifically literate students of the total number of students observed for a particular variable (e.g., gender) or one or more of a variable's categories (e.g., males and females). A higher or lower level of scientific literacy therefore corresponds to a respectively larger or smaller ratio of scientifically literate versus scientifically illiterate students. Frequencies of scientifically literate and scientifically illiterate individuals per category within specified variables were used to construct contingency tables, which were then analysed by conventional procedures and appropriate statistical techniques recommended by, for example, Everitt (1992).

In general, an overall chi-square test of independence was first performed on a  $2 \times c$  contingency table in order to establish whether the frequencies within the various categories of the variable under investigation deviate from a common ratio. A significant chi-square value indicated that the categories forming the table were not independent, that is an increased level of scientific literacy was associated with one or more of the categories. Further analyses were then performed in order to isolate sources of association within the table. Here the "... idea ... [was] to identify subtables that break up the chi-square statistic into more interpretable pieces, enabling those categories responsible for a significant overall chi-square value to be identified" (Everitt, 1992, p. 41). Methods recommended by Everitt (1992) for partitioning the overall chi-square value, as well as methods for partitioning the  $2 \times c$  contingency table into independent and non-independent  $2 \times 2$  tables, were used. In cases where specific hypotheses about particular  $2 \times 2$  tables were to be tested, the Fisher's Exact Test (Everitt, 1992) was employed.

## RESULTS AND DISCUSSION

Overall patterns of scientific literacy levels of a substantial sample of first-time entering students in the Western Cape provide a synoptic view of the recent educational system with respect to producing scientifically literate matriculants. Analyses of such patterns in greater detail, however, provide a more fine-grained assessment of the levels of scientific literacy that potentially highlight more subtle patterns amongst various groupings of students that are not evident from the aggregated data. Results with respect to both kinds of patterns are described in this chapter. In order to promote readability and to enhance coherence of the text, the majority of results are discussed and placed in context immediately after their

presentation. Major findings are, however, discussed and interpreted only in the latter part of this chapter.

### Overall patterns of scientific literacy levels

The overall level of scientific literacy of South African matriculants entering the five major tertiary educational institutions in the Western Cape for the first time was 36.2% (Table 6.1). Overall levels with respect to major student background variables and other variables related to tertiary education are as follows. There was a significant difference in the level of scientific literacy of students belonging to different population groups ( $\chi^2 = 329.22$ , d.f. = 3,  $p < 0.001$ ): approximately one in two White and Indian students were scientifically literate, whereas about one in four Coloured, and only one in ten African students were classified as such (Table 6.1). Although Indian students had the highest level of all

**Table 6.1.** A summary of the proportion (%) of scientifically literate high-school leavers for selected variables related to student background and tertiary education.

Variable	%	N
<b>All high-school leavers</b>	36.2	4227
<b>Population group</b>		
African	10.1	595
Coloured	27.0	1091
Indian	55.2	67
White	46.0	2470
<b>Gender</b>		
Male	40.6	2183
Female	31.5	2040
<b>Type of institution</b>		
Technikon	26.1	1519
University	41.8	2708
<b>Area of subject specialisation</b>		
Human Sciences	24.8	747
Commerce & Management	31.5	1644
Natural Sciences	45.2	1166
Engineering	51.0	557

four population groups (Table 6.1), there was no significant difference between the levels of scientific literacy of White and Indian students ( $\chi^2 = 1.86$ ,  $p > 0.05$ ).<sup>1</sup> The determination of the level of Indian

1. Degrees of freedom are not reported for this and subsequent  $2 \times 2$  contingency tables, as they are always 1 for such analyses.

students is, however, based on a very much smaller sample than that of other population groups (Table 6.1), and the high level of scientific literacy of this group therefore needs to be interpreted with great caution. In order to show reliably how patterns of scientific literacy are demographically determined amongst Indian matriculants, this population group will need to be sampled more extensively.

Overall, 40.6% of males were scientifically literate, whereas only 31.5% of females were classified as scientifically literate (Table 6.1). This difference was statistically highly significant ( $\chi^2 = 38.24$ ,  $p < 0.001$ ). Different levels of scientific literacy were also observed for students at universities and technikons, where about one in four technikon students and approximately two in five university students were scientifically literate (Table 6.1). The scientific literacy level of university students was statistically significantly higher than that of technikon students (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ). Students registered for degrees or diplomas in Engineering had the highest level of scientific literacy (51.0%), followed by students in the Natural Sciences (45.2%, Table 6.1). Next were students in Commerce and Management (31.4%), while students in the Human Sciences had the lowest level of scientific literacy (24.8%, Table 6.1). It is reasonable to assume that students registered for degrees and diplomas in Engineering and the Natural Sciences would be likely to display intrinsically higher levels of scientific literacy than students registered for courses in the Human Sciences and Commerce and Management. The overall pattern of levels of scientific literacy with respect to area of subject specialisation was therefore as anticipated. The difference between the level of scientific literacy of students in the Human Sciences and Commerce and Management was statistically significant ( $\chi^2 = 11.25$ ,  $p < 0.001$ ), as was the difference between the level of students in the Natural Sciences and Engineering ( $\chi^2 = 5.77$ ,  $p < 0.05$ ). Overall, Engineering students were thus the most scientifically literate of students entering the five major tertiary educational institutions in the Western Cape for the first time. This finding will be discussed later in this chapter.

Overall patterns amongst variables related to secondary education are described next. The level of scientific literacy of students with different overall matric results followed an anticipated trend: students with the highest aggregate - an 'A' - also displayed the highest level of scientific literacy, the levels of scientific literacy decreasing with lower aggregates (Table 6.2). Only one in ten students with an 'E', 'F', or 'G' matric result was scientifically literate, compared to almost seven out of ten students with an 'A' aggregate (Table 6.2). As expected, the number of science subjects taken in matric also influenced levels of scientific literacy. Only 10.2% of students who had taken no science subject were scientifically literate, whereas students who had taken at least one of the five most common subjects in the natural sciences in matric displayed a significantly higher level of scientific literacy (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ) than students who had taken none (Table 6.2). There was, however, no statistically significant difference in the overall scientific literacy level of students who had taken two or three science subjects in matric ( $\chi^2 = 3.60$ ,  $p > 0.05$ ).

Students who had taken different science subjects or different science subject combinations in matric also displayed different levels of scientific literacy. Students with Geography and Physical Science exhibited the highest level of scientific literacy, with almost three out of five such students being scientifically literate (Table 6.2). At the other end of the scale, students with only Biology, or only Geography, or Biology together with Geography had the lowest level of scientific literacy, with only one

**Table 6.2.** A summary of the proportion (%) of scientifically literate high-school leavers for different categories within selected variables related to secondary education.

Variable	%	N
<b>Overall matric result</b>		
A	68.2	554
B	50.7	912
C	34.3	1205
D	20.3	1133
E, F or G	10.3	370
<b>Number of science subjects</b>		
None	10.2	383
One	32.8	1277
Two	40.9	1944
Three	45.2	602
<b>Science subject(s)</b>		
Biology	19.9	574
Biology & Geography	22.9	384
Biology & Physical Science	44.2	1232
Physical Science	46.1	595
Biol. & Geog. & Phys. Sci.	46.9	561
Geography & Phys. Science	58.8	255
Geography	24.7	77
other subjects / combinations	22.7	145

out of five such students being scientifically literate (Table 6.2). In fact, overall there was no statistically significant difference in the level of scientific literacy of students who took these three subject combinations ( $\chi^2 = 1.83$ , d.f. = 2,  $p > 0.05$ ). Six out of 13 students who took only Physical Science in matric were scientifically literate and this level of scientific literacy is comparable to the level of those students who took Biology together with Geography and Physical Science (Table 6.2). Overall, however, there was no significant difference in the level of scientific literacy of students who took Physical Science alone, or Biology as well as Physical Science, or Biology together with Geography and Physical Science ( $\chi^2 = 1.33$ , d.f. = 2,  $p > 0.05$ ). The particular role of Physical Science in scientific literacy was highlighted by the fact that at least two out of five students with Physical Science in matric - either by itself or in combination with other science subjects - were scientifically literate (Table 6.2).

### Detailed analyses of patterns of scientific literacy levels

Given the great extent to which a student's population group would be expected to have shaped and dominated his or her schooling and educational experiences (Chapter 1), the population group variable necessarily needs to be taken into consideration in any analysis of South African educational data in order not to lose information in the aggregation of such data. The analyses of levels of scientific literacy of first-time entering students with respect to demographic and other variables related to tertiary educational institutions were therefore expanded to include population group as a further important descriptive variable. This expansion now makes it meaningful to include in the analyses additional variables (i.e., home language, age, tertiary institution, and examining authority) which were not discussed in the previous section.

#### *Population group and subject specialisation*

Students at each institution were sampled in areas of subject specialisation which made the greatest relative numerical contribution to the institution's overall first-time entering student population. Particular institutions and population groups were consequently over- and under-represented in certain disciplines (Chapter 5). Once such differences in the sample were taken into account in the analysis of the data, more subtle patterns of scientific literacy levels emerged. African students had the lowest level of scientific literacy in all four major areas of subject specialisation, and the hierarchy of increasing scientific literacy levels thereafter was Coloured, White and Indian<sup>2</sup> students in each area of subject specialisation (Table 6.3). However, whereas for both African and Coloured students the level of scientific literacy was highest in the Natural Sciences, for both Indian and White students the level was highest in Engineering. Given the educationally disadvantaged background of the majority of Black students, these differences in the level of scientific literacy of students belonging to different population groups are not unexpected (see relevant section later in this chapter).

Although in the total sample differences between the overall level of scientific literacy of students in the Human Sciences and Commerce and Management were statistically significant, this was not the case for African ( $\chi^2 = 2.02$ ,  $p > 0.05$ ), Coloured ( $\chi^2 = 0.86$ ,  $p > 0.05$ ), and White ( $\chi^2 = 0.57$ ,  $p > 0.05$ ) students. (For Indian students such a comparison was not possible because of the small sample size involved.) Similarly, statistically significant differences between the overall level of scientific literacy of students in the Natural Sciences and Engineering were not evident for African ( $\chi^2 = 0.12$ ,  $p > 0.05$ ),

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2. The reader is again reminded that the high level of scientific literacy of Indian students must be treated with caution because of the small sample of Indian students.



Coloured ( $\chi^2 = 0.51$ ,  $p > 0.05$ ), Indian ( $\chi^2 = 0.40$ ,  $p > 0.05$ ), and White ( $\chi^2 = 0.41$ ,  $p > 0.05$ ) students. For all population groups, therefore, differences in scientific literacy only appear to occur at very coarse levels of differentiation such as between what could be termed the sciences and the non-sciences.

**Table 6.3.** The proportion (%) of scientifically literate high-school leavers by area of subject specialisation and population group. The sample size in each case is given in parentheses.<sup>3</sup>

Area of subject specialisation	African	Coloured	Indian	White	Total
Human Sciences	4.6 (218)	16.4 (171)	N/A (7)	40.7 (351)	24.8 (747)
Commerce & Management	8.8 (147)	19.7 (386)	45.0 (20)	38.5 (1089)	31.5 (1642)
Natural Sciences	19.1 (162)	38.3 (381)	61.5 (26)	55.9 (597)	45.2 (1166)
Engineering	17.1 (35)	34.9 (109)	72.7 (11)	58.0 (400)	51.2 (555)

### *Gender*

Overall, there was a statistically significant difference between the level of scientific literacy of male and female students, levels being higher for the former than for the latter group (Table 6.4). Males displayed higher levels of scientific literacy than females in all population groups - results which on the whole are in accordance with the widely documented association between gender and general achievement in science (see, for example, references cited in Kelly [1981, 1987a, 1987b]). A significantly greater proportion of male (60%) than female (40%) students took science subject combinations that included Physical Science (Fisher's Exact Test [ $p < 0.00001$ ]), and it is well-known that girls are generally underrepresented in physics (see, for example, Kelly [1987a]). As Physical Science plays a particular role in the scientific literacy of matriculants (see below), the difference in science subject combination of male and female students probably accounts for the difference in scientific literacy levels between genders.

However, statistically significant gender-based differences in levels of scientific literacy were found only for African and White students and not for Coloured and Indian students (Table 6.4), suggesting that female students in the latter population groups may differ in some respect from females of the former

3. In this and subsequent tables in this chapter, some information provided in Table 6.1 and Table 6.2 above may be repeated for the convenience of the reader.

groups. Further analyses revealed that African and White female students on the one hand, and Coloured and Indian female students on the other, did not differ with respect to, for example, the proportion of students with a holiday job related to science ( $\chi^2 = 0.46$ ,  $p > 0.05$ ), science club membership at school ( $\chi^2 = 1.24$ ,  $p > 0.05$ ), and participation in science fairs ( $\chi^2 = 2.73$ ,  $p > 0.05$ ). However, 64% of female Coloured and Indian students either took Biology in addition to Physical Science, or Biology together with Geography and Physical Science, in matric in comparison to only 41% of female African and White students. This is a statistically significantly higher proportion (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ), and it is speculated that the difference in subject choice may have contributed in some manner to why Coloured and Indian female students appear to be somewhat more scientifically literate in comparison with their male peers than African and White female students.

**Table 6.4.** The proportion (%) of scientifically literate male and female high-school leavers by population group. The sample size in each case is given in parentheses. The value of the  $\chi^2$ -statistic and the corresponding significance level for the gender comparison within each population group and for the total sample are also presented.

	African	Coloured	Indian	White	Total
Male	13.6 (250)	29.8 (493)	57.9 (38)	48.8 (1399)	40.6 (2180)
Female	7.5 (345)	24.9 (595)	51.7 (29)	42.3 (1070)	31.5 (2039)
$\chi^2$ -statistic	5.23	3.09	0.065	10.00	38.24
sign. level	$p < 0.05$	ns*	ns*	$p < 0.005$	$p < 0.0001$

\* not significant ( $\alpha = 0.05$ )

### *Home language*

Home language was used together with examining authority to derive the population group of students (Chapter 5). As levels of scientific literacy with respect to the nine official Black languages spoken in South Africa would thus only mimic the levels of scientific literacy already identified for African students, the description and discussion of patterns of levels with respect to home language is restricted to English only, Afrikaans only, and English together with Afrikaans. The overall level of scientific literacy of students with these home languages was 51.9%, 29.8%, and 41.5%, respectively, and there was a significant difference between these levels of scientific literacy ( $\chi^2 = 162.03$ , d.f. = 2,  $p < 0.001$ ). This result suggests that levels of scientific literacy decrease with an increasing predominance of

Afrikaans in the home language category. It is possible that this result could be interpreted to reflect on the language robustness of the *Test of Basic Scientific Literacy* (TBSL) which may - in the light of the above findings - appear to potentially disadvantage, for example, Afrikaans-speaking students. The issue of language-bias of the TBSL clearly warrants further investigation and is therefore addressed below.

### *Potential test-bias*

As was shown earlier, levels of scientific literacy are dependent on population group and subject area specialisation (Table 6.3). In a valid comparison of scientific literacy levels with respect to particular home languages, both population group and subject area specialisation therefore need to be controlled. The group of students who reported either English, or Afrikaans, or English and Afrikaans as their home language consisted of four African and 67 Indian students, as well as of 1088 and 2393 Coloured and White students, respectively. The sample size of African students was clearly too small to allow any comparisons to be made, and as 57 of the 67 Indian students reported English as their home language, comparisons for Indian students were also not possible. The investigation of possible test-bias with respect to Afrikaans was therefore limited to Coloured and White students.

Neither for Coloured ( $\chi^2 = 3.51, p > 0.05$ ) nor for White ( $\chi^2 = 0.067, p > 0.05$ ) students was there a significant difference between the levels of scientific literacy of English-speaking and English- and Afrikaans-speaking students. These two language categories were therefore combined. There was a significant association between Afrikaans and the combined language categories and all four areas of subject specialisation for Coloured ( $\chi^2 = 12.31, \text{d.f.} = 3, p < 0.01$ ) but not for White ( $\chi^2 = 6.95, \text{d.f.} = 3, p > 0.05$ ) students. These results indicate that Coloured Afrikaans-speaking students occurred proportionally more frequently in one or more areas of subject specialisation than students with other home languages, but that such an occurrence was not the case for White students. Hence only Coloured students were considered further. For Coloured students, there was no association between language classification (Afrikaans and the combined categories of English and English together with Afrikaans) and the subject disciplines of Engineering, Natural Sciences, and Commerce and Management ( $\chi^2 = 0.77, \text{d.f.} = 2, p > 0.05$ ). These three subject areas were therefore combined into a non-Human Sciences category. Finally, a  $2 \times 2$  table of the language classification versus the Human and non-Human Sciences was constructed. A chi-square analysis revealed a significant association between these variables ( $\chi^2 = 11.55, p < 0.001$ ) which showed that there were proportionally more Afrikaans-speaking students in the Human Sciences than in the non-Human Sciences.

As the level of scientific literacy of students in the Human Sciences was the lowest for almost all population groups irrespective of home language (Table 6.3), it is very likely that amongst Coloureds, Afrikaans-speaking students displayed lower levels of scientific literacy than English-speaking students because more Afrikaans-speaking students came from the Human Sciences. For Afrikaans-speaking

White students this explanation does not appear to hold, as White students were not over-represented in any particular area of subject specialisation. The above results partially support an alternative explanation of the patterns of scientific literacy levels encountered with respect to Afrikaans-speaking students, and the results thus provide conflicting evidence for the existence of a language-bias of the TBSL. The above investigation, however, also suggests a number of hypotheses that may be useful directions for further research in this respect.

### *Age group*

In general, levels of scientific literacy differed significantly between age groups, with 18- and 19-year-olds displaying the highest level, and students older than 20 years displaying the lowest level of scientific literacy (Table 6.5). Age data were aggregated at either end of the age range in order to obtain a sufficiently large number of observations to allow statistical analyses to be carried out. Results revealed that 18- and 19-year-old students exhibited significantly higher levels of scientific literacy than students of other ages within the 16- to 23-year age range ( $\chi^2 = 66.07$ ,  $p < 0.001$ ). In general, the youngest students achieved highest levels within each population group (Table 6.5), and African students displayed the lowest level of scientific literacy in all age groups. Whereas there were statistically significant differences between levels of scientific literacy of students of different ages for Coloured and White students, no such differences existed for African and Indian students (Table 6.5). Further analyses revealed that Coloured students 18 years old or younger displayed significantly higher levels of scientific literacy than older Coloured students (Fisher's Exact Test [one-tailed],  $p < 0.05$ ). Similarly, 18-year-old White students were significantly more scientifically literate than White students of other ages (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ). The high level of scientific literacy of the small group of oldest White students is speculated to be attributable to students who completed military training, worked, or travelled for some time before deciding on a course of study at tertiary institutions, and who are thus more mature, experienced and potentially more motivated than younger students.

In general, the above results indicate that students completing high-school at a 'normal' age (i.e., at age 18 after the usual 12 years of schooling) also display the highest levels of scientific literacy whereas older students display lower levels. The large proportion of African students amongst the older students very probably accounts for this pattern amongst students of combined population groups, as African students were shown earlier to have the lowest level of scientific literacy overall. Nevertheless, it is plausible that students of other population groups matriculate later because they are academically weaker than their younger peers and hence potentially also less likely to be scientifically literate. (An attrition-of-information-with-age explanation must be excluded as all students had completed high-school within the last two years, thus eliminating the possibility that students had started to forget what had been learnt at

school earlier.) One could also speculate that students matriculate later precisely because they are less scientifically literate. However, as the line of causality between scientific literacy and age is not known and cannot be established here, this explanation needs to be interpreted with circumspection.

**Table 6.5.** The proportion (%) of scientifically literate high-school leavers by age and population group. The sample size in each case is given in parentheses. The value of the  $\chi^2$ -statistic and the significance level for corresponding degrees of freedom (d.f.) for the age comparison within each population group and for the total sample are also presented.

Age	African	Coloured	Indian	White	Total
16-17	16.1 (31)	63.6 (11)	N/A (1)	N/A (5)	29.2 (48)
18	7.8 (102)	30.2 (394)	60.9 (23)	55.2 (453)	40.2 (972)
19	13.4 (142)	26.0 (535)	54.8 (42)	44.8 (1671)	38.9 (2390)
20	9.4 (128)	20.8 (125)	N/A (1)	40.9 (301)	29.1 (554)
21-23	8.3 (192)	13.3 (30)	- (-)	46.7 (37)	13.1 (259)
$\chi^2$ -statistic	4.24	14.03	0.23	21.56	86.72
d.f.	4	4	1	3	4
sign. value	ns*	$p < 0.01$	ns*	$p < 0.001$	$p < 0.001$

\* not significant ( $\alpha = 0.05$ )

A noteworthy observation is the fact that the level of scientific literacy of African students does not display a distinct decreasing trend with age in comparison to most other population groups (Table 6.5). (The sample size for Indian students appears to be too small for any pattern to manifest itself.) A likely explanation is that the age spread of pupils enrolled in Std 10 is much greater for African pupils than for pupils of other population groups. In 1991, for example, 69.2% of African pupils enrolled in Std 10 were 19-years or older, compared to 22.7%, 2.6%, and 3.7% of Coloured, Indian, and White pupils, respectively (EduSource, 1994a). Furthermore, repetition rates of African students in senior high school are very high, reaching, for example, well over 20% in Std 9 and 10 in 1991 (EduSource, 1994a). In comparison to other population groups, a much greater proportion of older African pupils is thus still at school, which suggests that the effect of schooling on scientific literacy - which is assumed here to be positive - is of longer duration for African students than for other students entering tertiary educational

institutions. The level of scientific literacy of African students would therefore not necessarily decrease with age as for Coloured or White students.

### *Institutions and areas of subject specialisation*

The scientific literacy level of university students was shown earlier to be significantly higher than that of technikon students (see above). It is possible that this difference may be due to a different academic potential of university and technikon students. It is not unreasonable to assume that overall matric result is a rough indicator of a student's academic ability. For White students, 50% of first-time entering students at technikons obtained a 'D', 'E', or 'F' in matric, compared with only 8% of first-time entering students at universities. This is a significantly higher proportion (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ). (The comparison of student profiles of matric results is restricted to White students in order to avoid the debate on whether matric result is indeed a reliable indicator of academic potential for Black students in the light of educational disparities that have been created as a result of apartheid policies [see references cited in, for example, Bockhorst, Foster, & Lea, 1992].) There is thus some indirect evidence that students at technikons are likely to be of lower general academic ability than students at universities. This difference in student ability may well account for the difference in the level of scientific literacy, as it would be surprising if scientific literacy is not related to academic ability in some manner. For example, academically more able students would appear to be more likely to have taken subjects in matric that are generally labelled as 'difficult'. Physical Science and Mathematics are examples of such subjects (FRD, 1993), and taking the former in matric must be regarded as an advantage to becoming scientifically literate (see below). A further possible link between scientific literacy and academic ability will be reading habits. Experience leads one to believe that academically more able students are likely to read both more widely and more selectively than academically less able students. The reading habits of academically more able students may thus increase the chance that they obtain the required knowledge about, and insight into, science in order to be classified as scientifically literate.

There were significant differences between the overall levels of scientific literacy of students from all institutions (Table 6.6). Although it is tempting to do so, it is not meaningful to compile a ranking of the overall level of students from individual institutions, as samples from four out of the five institutions are biased with respect to population group (Chapter 5, Table 5.10, p. 104). Moreover, the first-time entering student-body at the Peninsula Technikon and at the University of the Western Cape was inadequately sampled (Chapter 5). It is thus more appropriate to examine patterns of scientific literacy levels of students in individual areas of subject specialisation.

With the exception of the Peninsula Technikon, Engineering students consistently displayed the highest level of scientific literacy within each institution (Table 6.6). However, not all engineering students at the Peninsula Technikon were sampled (Chapter 5), thus potentially misrepresenting the level of scientific literacy of engineering students at this institution. The two highest levels of scientific literacy of students in the four areas of subject specialisation at all five institutions was displayed by Engineering and Natural Sciences students at the University of Cape Town, where almost seven out of ten students were classified as scientifically literate (Table 6.6). Engineering students at the University of Stellenbosch displayed the third highest level of scientific literacy, but no significant difference existed between the University of Cape Town and the University of Stellenbosch Engineering students ( $\chi^2 = 0.48, p > 0.05$ ).

**Table 6.6.** The proportion (%) of scientifically literate high-school leavers by tertiary educational institution and area of subject specialisation. The sample size in each case is given in parentheses. The value of the  $\chi^2$ -statistic and the significance level for the corresponding degrees of freedom (d.f.) for the comparison of overall levels of scientific literacy and for the comparison of levels within each area of subject specialisation are also presented.

Institution	Human Sciences	Comm. & Mngmnt	Natural Sciences	Engineering	Total
CT	- (-)	23.6 (580)	33.2 (286)	43.7 (261)	30.7 (1127)
PT	- (-)	7.5 (227)	21.9 (114)	17.6 (51)	13.0 (392)
UCT	19.4 (216)	57.1 (354)	67.1 (249)	67.7 (130)	52.6 (949)
US	38.1 (328)	34.0 (459)	54.3 (282)	63.5 (115)	42.8 (1184)
UWC	8.9 (203)	25.0 (24)	37.0 (235)	- (-)	24.0 (462)
$\chi^2$ -statistic	62.17	186.30	105.26	49.96	265.91
d.f.	2	4	4	3	4
sign. value	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.001$

The level of scientific literacy of students within different areas of subject specialisation varied, and significant differences existed between the level of scientific literacy of students from different institutions within every subject specialisation (Table 6.6). Two groups of students were found to have unexpectedly high levels of scientific literacy in comparisons with students in the same subject discipline

from other institutions, namely University of Stellenbosch students in the Human Sciences, and University of Cape Town students in Commerce and Management (Table 6.6). The student sample in the Human Sciences at the University of Stellenbosch was largely White (82%), whereas the majority of students in the sample at the University of Cape Town (61%) and at the University of the Western Cape (98%) were African and Coloured. As students in the latter population groups displayed lower levels of scientific literacy than students in the former population group (Table 6.6), the composition of the student sample may well account for the unexpectedly high levels of scientific literacy of students in the Human Science at the University of Stellenbosch. The high level of scientific literacy of students in Commerce and Management at the University of Cape Town is likely to be the result of very high entrance requirements that the Faculty of Commerce is in a position to apply in order to select students for admission (University of Cape Town, 1994). Many of the Commerce and Management students are therefore likely have taken an academic stream in senior high-school which will in all probability have included Physical Science. Support for this argument comes from the fact 82% of all UCT Commerce and Management students who indicated their science subject combination in the survey questionnaire ( $n = 314$ ) took Physical Science in matric. Given the important role of this subject in the scientific literacy of matriculants (see below), it is not surprising that students in the Commerce and Management sample at the University of Cape Town displayed high levels of scientific literacy.

### *Examining authority*

Until after the elections in April 1994, the examining authorities (i.e., usually departments of education) for South African secondary school-leaving examinations were essentially racially based (Chapter 1). Levels of scientific literacy of students from different examining authorities thus need to be investigated within their corresponding population groups, in order to achieve a meaningful comparison of examining authority. Examining authority was, however, used as the sole criterion to derive the population group of Coloured and Indian students (Chapter 5), and the level of scientific literacy of students from these two examining authorities would thus mimic the level of scientific literacy of Coloured and Indian students. Hence, the examining authority for these students is not considered further here. The great majority of African students (73.7%) in the overall sample came from the Department of Education and Training, with students from the Transkei Education Department representing 9.4%. The remaining 100 African students in the overall sample (16.9%) were distributed amongst eight of the other examining authorities mentioned above, and each of these authorities therefore contained a sample size of African students too small to justify meaningful descriptions and statistical comparisons. With 8.9% of students from the Department of Education and Training ( $n = 437$ ) being classified as scientifically literate, students from this examining authority displayed a higher level of scientific literacy than students from the Transkei



Education Department ( $n = 56$ ), where only 3.6% were classified as scientifically literate. The difference between the two groups was, however, not statistically significant ( $\chi^2 = 1.87, p > 0.05$ ).

Levels of scientific literacy of White students from different examining authorities are presented in Table 6.7. Students from the Joint Matriculation Board/Independent Examinations Board and Natal Education Department displayed the highest levels of scientific literacy, whereas students from the Cape

**Table 6.7.** The proportion (%) of scientifically literate White high-school leavers for different examining authorities.

Examining authority	%	N
JMB/IEB	67.8	59
Natal Education Department	66.7	105
Transvaal Education Department	52.7	207
National Senior Certificate	44.0	75
Cape Education Department	43.8	1982
Orange Free State Education Dept	40.5	42

and Orange Free State Education Departments displayed the lowest levels (Table 6.7). The low level of scientific literacy of students of the Cape Education Department in comparison to students of other examination authorities, is most probably due to the fact that students from other examining authorities studying at tertiary educational institutions in the Western Cape are very frequently self-selected, that is, they do not come from the Western Cape. Experience from several South African universities and technikons shows that local students tend to dominate the intake of students at a particular tertiary institution. The present sample of 4227 students entering the five major educational institutions in the Western Cape for the first time is no exception: students from the Cape Education Department constituted 80.2% of the sample of White students. The remaining White students came from examining authorities of other provinces but may be atypical in comparison to the overall student-body of those provinces' examining authorities, as students studying at tertiary institutions other than at their local one do so for a variety of reasons (e.g., because of financial incentives such as scholarships, being accepted in a preferred course of study, academic excellence, etc.). In addition to being numerically relatively small, the samples of students from other examining authorities are therefore not necessarily representative, and patterns of levels of scientific literacy with respect to examining authority of White students are thus likely to be spurious and need to be interpreted with caution.

*Number of science subjects*

General results of the influence of the number of science subjects on the level of scientific literacy of all students were described earlier (see above). In this section the essential concern is whether students taking different numbers of science subjects in matric also display different levels of scientific literacy. It would be reasonable to expect students with a higher number of science subjects in matric to have acquired knowledge about a larger number of science concepts than students who took fewer science subjects. At the very least, the former group of students could be expected to have their existing knowledge in science consolidated, if not necessarily increased, compared to the latter group of students. Students taking a larger number of science subjects would therefore be expected to display a higher level of scientific literacy than students who only took one - or even no - science subjects in matric.

Levels of scientific literacy with respect to the number of science subjects within different population groups are given in Table 6.8. As anticipated, levels of scientific literacy of students who took no science subject in matric were generally low for all population groups (Table 6.8). For African and Coloured students, the level of scientific literacy was highest when taking two science subjects and decreased somewhat when taking a third one, whereas for White students there was a consistent increase in the level of scientific literacy for each increase in the number of science subjects taken in matric (Table 6.8). The sample size of Indian students was too small to render meaningful any apparent trend over the complete range of the number science subjects taken (Table 6.8).

**Table 6.8.** The proportion (%) of scientifically literate high-school leavers by population group and number of science subjects taken in matric. The sample size in each case is given in parentheses.

No. of science subjects	African	Coloured	Indian	White	Total
0	2.4 (85)	8.2 (159)	N/A (1)	16.8 (137)	10.2 (382)
1	5.6 (107)	16.9 (195)	37.5 (16)	39.0 (959)	32.8 (1277)
2	13.3 (316)	34.9 (455)	56.8 (44)	50.4 (1127)	40.9 (1942)
3	11.9 (84)	32.8 (274)	N/A (6)	70.5 (237)	45.3 (601)

For African students there was no statistically significant difference in the level of scientific literacy of students who took one and no science subject in matric ( $\chi^2 = 0.57$ ,  $p < 0.05$ ), whereas a significant difference did exist for such a comparison of scientific literacy levels for Coloured ( $\chi^2 = 5.30$ ,  $p < 0.05$ ) and White ( $\chi^2 = 25.60$ ,  $p < 0.001$ ) students. Indian students taking two science subjects did not have a significantly different level of scientific literacy from those taking only one science subject in matric ( $\chi^2 = 1.07$ ,  $p > 0.05$ , with Yates' correction). White students who took three science subjects displayed significantly different levels of scientific literacy from students who took only two subjects ( $\chi^2 = 31.73$ ,  $p < 0.001$ ). However, no such differences existed for African ( $\chi^2 = 0.11$ ,  $p > 0.05$ ) and Coloured ( $\chi^2 = 0.33$ ,  $p > 0.05$ ) students.

In general, therefore, students taking at least one science subject up to matric are also very likely to display higher levels of scientific literacy than students who take no science subject. It is, however, not necessarily true that students taking three science subjects in matric inevitably have higher levels of scientific literacy than students taking only two science subjects. Different science subjects, and combinations of them, may, of course, influence the level of scientific literacy of students, and this issue is examined in the following section.

### *Science subject combinations*

The six science subjects and subject combinations presented in Table 6.9 cater for the choice of science subjects taken in matric by 94.2% of all 3823 students who responded to the appropriate question (Question 10) in the survey questionnaire (Appendix G, pp. 309-330). At a first glance, African and Indian students who took Biology together with Physical Science appeared to be the most scientifically literate individuals compared with other students within their respective population groups who took different science subject combinations. Coloured students with Physical Science, and White students with Biology as well as Geography and Physical Science, displayed the highest level of scientific literacy within their respective population groups (Table 6.9). The difference in the level of scientific literacy of students who took Biology alone, and Biology together with Geography was not significant for African ( $\chi^2 = 0.014$ ,  $p > 0.05$ ), Coloured ( $\chi^2 = 2.18$ ,  $p > 0.05$ ), or White ( $\chi^2 = 2.54$ ,  $p > 0.05$ ) students. Similarly, there was no statistically significant difference in the level of scientific literacy of White students who took Biology only, or Geography only, or Biology together with Geography ( $\chi^2 = 2.64$ , d.f. = 2,  $p > 0.05$ ). There was no significant difference in the level of scientific literacy of students who took Physical Science alone, Biology together with Physical Science, and Biology along with Geography and Physical Science, within African ( $\chi^2 = 0.58$ , d.f. = 2,  $p > 0.05$ ), Coloured ( $\chi^2 = 3.58$ , d.f. = 2,  $p > 0.05$ ), and White ( $\chi^2 = 2.54$ , d.f. = 2,  $p > 0.05$ ) population groups. The difference in the level of

scientific literacy of Indian students with Physical Science alone, and Biology as well as Physical Science was also not statistically significant ( $\chi^2 = 3.57$ ,  $p > 0.05$ ). The sample size of Indian students who took other science subject combinations was, however, unfortunately too small to justify further comparisons within this population group (Table 6.9).

In general, therefore, three patterns of levels of scientific literacy with respect to science subject combination can be identified. Firstly, Physical Science plays an important role in the scientific literacy of high-school leavers, as the level of scientific literacy of students including Physical Science in their science subject combination was consistently higher than for student who did not include this subject. Secondly, there is consistent evidence that the effect on scientific literacy of taking Biology and Biology together with Geography in matric is similar and not additive. In terms of levels of scientific literacy there therefore seems to be no apparent advantage to taking Geography in addition to Biology. Thirdly, African students consistently had the lowest level of scientific literacy of all population groups in every science subject combination, and displayed levels that were only one third to one fifth as high as students in the population group with the highest scientific literacy level (Table 6.9).

**Table 6.9.** The proportion (%) of scientifically literate high-school leavers for the most frequent science subject combinations by population group. The sample size in each case is given in parentheses.

Science subject combination	African	Coloured	Indian	White	Total
Biology	5.0 (80)	13.6 (162)	N/A (6)	26.7 (326)	19.9 (574)
Biology & Geography	6.6 (91)	20.2 (119)	N/A (4)	33.5 (170)	22.9 (384)
Biology & Physical Science	18.1 (188)	40.2 (336)	61.1 (36)	52.7 (670)	44.2 (1230)
Physical Science	16.7 (12)	41.7 (24)	50.0 (10)	46.8 (549)	46.1 (595)
Biol. & Geog. & Physical Science	13.8 (58)	33.0 (273)	N/A (6)	71.7 (223)	47.0 (560)
Geography & Physical Science	N/A (4)	- (-)	N/A (4)	59.9 (247)	58.8 (255)
Geography	N/A (8)	N/A (8)	- (-)	31.1 (61)	24.7 (77)

## General

A number of important general results with respect to patterns of levels of scientific literacy of first-time entering students at the five major tertiary educational institutions in the Western Cape were evident from the above analyses. These results include the role of Physical Science in scientific literacy, the similarity of effect of Biology and Geography on scientific literacy, the high level of scientific literacy displayed by Engineering students, and the hierarchy of levels of scientific literacy consistently displayed by students of different population groups. Each of these findings is now discussed in greater detail.

### *The role of Physical Science in scientific literacy*

The level of scientific literacy - as measured by the TBSL - of students who included Physical Science in their science subject combination was about twice as high as that of students who did not take Physical Science (Table 6.2). This general pattern of the significance of Physical Science applied to students of all population groups, and the level of scientific literacy of students who took Physical Science in matric was consistently higher than that of students who did not (Table 6.9). In the light of the above findings, Physical Science plays an important role in the scientific literacy of high-school leavers in contrast to other subjects, such as, for example, Biology. Why should this be so? The *Test of Basic Scientific Literacy* (TBSL) is not numerically biased with respect to test-items in the physical and chemical sciences. These items, in fact, constitute the lowest proportion of test-items in any content area covered by the TBSL (Chapter 4, Table 4.2, p. 70), so that students taking Physical Science were not advantaged by the method in which their scientific literacy was assessed.

Answers to the above question therefore need to be sought elsewhere, and to this end it will be useful to identify possible differential effects of Physical Science and Biology on the students' scores on the *Test of Basic Scientific Literacy*. A comparison of the two science subjects was obtained in the following manner. Students who took no natural science subjects ( $n = 383$ ) and students who included only Physiology and/or Agricultural Science in their science subject choice ( $n = 31$ ) were regarded as the control group against which the effects of Physical Science and Biology could be determined. In order to achieve meaningful comparisons, only students who included Physical Science but no Biology in their science subject combination were allocated to the Physical Science group. Similarly, only students who included Biology but no Physical Science in their science subject combination were assigned to the Biology group. As previous results indicated that the effect of Geography on scientific literacy may be similar to that of Biology (Table 6.9), students who took Geography were excluded from all three groups.

The mean score ( $\pm SD$ ) per subtest of the TBSL for the three student groups are presented in Table 6.10. Mean scores on all subtests were higher for students in the Biology and Physical Science group than in the control group, suggesting that both science subjects influenced the scientific literacy of students positively. In contrast to the Physical Science group, however, no statistically significant differences existed between the Biology and control groups (Table 6.10). Nevertheless, it is the increase in mean scores as a result of taking different science subjects that is important here, as students were required to meet performance standards on each TBSL subtest in order to be classified as scientifically literate (Chapter 4). Students needed to achieve a score of at least 13 out of 22 on the Nature of Science Subtest (NSST), 45 out of 72 on the Science Content Knowledge Subtest (SCKST), and 10 out of 16 on the Impact of Science and Technology on Society Subtest (ISTSST) in order to be classified as scientifically literate (Chapter 4). As can be seen from Table 6.10, the mean score of students taking Physical Science was above the performance standard on all three subtests, whereas the mean score of students taking Biology remained below the performance standard on all subtests.

**Table 6.10.** The mean score ( $\pm SD$ ) per subtest of the TBSL for a control group and for students with science subject combinations that included Physical Science and Biology. Geography was excluded from all groups (see text for details).

<i>Test of Basic Scientific Literacy Subtest</i>	Control ( <i>n</i> = 414)	Phys. Science ( <i>n</i> = 626)	Biology ( <i>n</i> = 615)
Nature of Science Subtest (NSST)	10.9 $\pm$ 4.0	13.7 $\pm$ 3.5*	11.5 $\pm$ 3.8
Science Content Knowledge Subtest (SCKST)	33.0 $\pm$ 13.2	47.2 $\pm$ 12.1*	39.9 $\pm$ 12.8
Impact of Science and Technology on Society Subtest (ISTSST)	7.9 $\pm$ 3.5	10.3 $\pm$ 3.3	8.2 $\pm$ 3.5

*Note.* Asterisks indicate significant differences (*t*-test) between the mean score of students with Physical Science and the control group ( $\alpha = 0.05$ ).

These results are important as they suggest a mechanism through which Physical Science impacts on the scientific literacy of matriculants. Averaged over all students, individuals who took Physical Science are shown to have a better understanding of the nature of science than students who took Biology. The former group also has an increased awareness of the impact of science and technology on society compared with the latter group, despite a lack of a statistical significance when compared with the control group. In addition, students taking Physical Science in matric are shown to have an understanding of a larger number of important concepts in science than students with Biology. What follows are possible explanations for the superior performance on each dimension of the TBSL of students who took Physical Science in comparison with students who took Biology. Each dimension is addressed in turn.

Firstly, the nature of science. In the classroom, teaching particular concepts in Physical Science is often approached from a historical perspective. For example, teaching the model of the atom in the South African syllabus requires a conceptual voyage from the single indivisible particle of Dalton to Thomson and the discovery of the electron, to Rutherford and his model of the nuclear atom, before ending with Bohr and the orbital model of the atom. During this teaching process, the ideas underlying a number of key experiments in physics need to be discussed and explained. It seems probable that through such a process pupils are likely to become more familiar with the way scientists think, how science proceeds, and what the limitations of science are. While this increased familiarity with the nature of science will in all probability be comparatively unsophisticated, the familiarity is nevertheless likely to be greater than that of pupils taking only Biology. Examination of the senior secondary syllabus in Physical Science and Biology indicates clearly that in the senior secondary phase a larger number of principles in the physical and chemical sciences are expected to be taught with at least some rudimentary historical perspective than in the biological and health sciences (personal observation). It is therefore possible that the greater historical contextualisation of topics believed to be occurring in Physical Science is responsible for the fact that students taking Physical Science have a better understanding of the nature of science than students taking Biology.

With respect to science content knowledge, it is hypothesised that a higher proportion of test-items in the biological and health sciences may be easier to answer correctly without formal education in these areas than in the physical and chemical sciences. Tamir (1991), for example, investigated the acquisition of functional knowledge and understanding of selected concepts in physics, chemistry, and biology in a study of 554 Israeli 10th grade (year 8) pupils. He found that biology was the only subject in which functional knowledge was significantly related to non-formal science activities such as, for example, watching television science programmes, listening to radio science programmes, and reading on science topics. Some of the concepts addressed in the content area of the biological sciences in the TBSL are of an ecological and environmental nature (e.g., ecosystems, the importance of species diversity, greenhouse effect), and it is believed that such topics receive fairly regular coverage on television and in newspapers. It is similarly believed that topics in the health sciences receive frequent airing in broadcast and print media. Although there are no data in this area available for South Africa, these assumptions are to some extent supported by studies in the United Kingdom, which show that medical issues, ecology, and the environment dominate newspaper coverage of science (Hutton, 1996; Wellington, 1991). It thus seems possible that items in both the biological and health sciences may be answered correctly not only because of exposure to formal education in these areas but also because of non-formal involvement in science through, for example, reading newspapers. Concepts in the physical and chemical sciences, on the other hand, are more abstract and theoretical in nature (e.g., energy, motion, forces), and are likely to receive less coverage in any of the news media. Both Hutton (1996) and Wellington (1991) found that issues

related to physics and 'pure science' received much less newspaper coverage than medical issues, ecology or the environment. Test-items in the physical and chemical sciences are therefore less likely to be answered correctly without exposure to formal education than items in the biological and health sciences. It is thus hypothesised that Physical Science students are able to correctly answer a greater proportion of test-items in content areas related to the biological and health sciences than Biology students are able to do in areas related to the physical and chemical sciences.

A comparison of mean scores of Physical Science and Biology students for the test-items in the physical and chemical, as well as biological and health, sciences lends support to this argument. Converting mean score to a percentage, Physical Science and Biology students correctly answered 69% and 46% of the 14 test-items in the physical and chemical sciences, respectively. The percentage of items answered correctly for the 43 items in the biological and health sciences was 64% and 60% for the former and latter group, respectively. The percentages of correctly answered test-items thus fit the hypothesised pattern. Although mean scores for Physical Science and Biology students for each group of sciences were not statistically significantly different (in each comparison the *p*-value was greater than 0.05), these results provide support for a hypothesised explanation that accounts for the fact that students who took Physical Science as a science subject in matric scored higher on the SCKST than students who took Biology.

A considerable number of test-items in the Impact of Science and Technology on Society Subtest are related to technology (Appendix G, pp. 309-330). In fact, the words "technology", "technologies", and "technological" appear in nine of the 16 test-items of the ISTSST. Reasons why Physical Science students do better on the ISTSST than Biology students may be related to the greater obvious connection at a first glance between technology and Physical Science than between technology and Biology at school science level. It is not being argued here that biological concepts do not have any connection to technology - clearly this would be erroneous - but rather that such connections may be more obvious without teacher intervention to students in Physical Science than in Biology. For example, there are many everyday examples of technology that are based on physical concepts covered in the South African Physical Science syllabus. Such concepts include waves, light, sound, electricity and electrical current, chemical reactions, heat and work, motion, radioactivity, and so forth. However, the relative number of obvious everyday examples of technology which are based on biological concepts covered in the Biology syllabus are lower than in the Physical Science syllabus (personal observation). Examples of such biological concepts are largely related to health and may include aspects of human anatomy and physiology, genetics, and nutrition. It is thus speculated that because of differences in the syllabus content, Physical Science students will in all probability have a comparatively clearer understanding of technology and the issues surrounding its application than Biology students. It therefore follows that compared to Biology students, Physical Science students have an advantage in answering the test-items



related to the impact of science and technology on society, and hence are likely to achieve a higher score on the relevant subtest.

In the preceding paragraphs, explanations have been offered that may potentially account for the superior performance of Physical Science students on each of the three subtests of the TBSL compared with, for example, Biology students. These explanations were largely related to differences in the syllabus content between the two science subjects, and the explanations thus had as their focus the school subjects rather than the students. It is, of course, also possible that Physical Science students have different personal attributes to Biology students (such as, for example, higher intelligence [e.g., Collings & Smithers, 1983], a more pronounced career orientation, etc.) that might influence the students' performance on the TBSL. For example, it has been shown that students interested in different sciences at school also have different psychological profiles (Collings & Smithers, 1983) and self-perceived personality traits (Woolnough, 1994, 1995). In a study of about 1900 sixth-formers in England taking science and non-science subjects, Collings and Smithers (1983) found that students in the physical sciences appeared more tough-minded and less person-orientated than the biologists, and physical scientists also attached relatively low importance to working with people and helping them. In addition, a higher proportion of physical scientists were classified as convergent thinkers, whereas proportionally more biologists were classified as divergent thinkers (Collings & Smithers, 1983). In general, Collings and Smithers (1983, p. 14) concluded that "the differences between physical and biological scientists tend to be of the same kind as those between scientists as a whole compared to non-scientists". In a study of over 1200 sixth-formers in schools throughout England, Woolnough (1995) identified particular personality trait groupings for different science students based on the student's own perception of their personality. For example, biologists considered themselves hard-working, clever, and conscientious, and thought they communicated best in words (Woolnough, 1995). However, a picture of being "clever, mercenary, more interested in ideas than people, more sober than enthusiastic, more tough- than tender-minded, more of a loner than gregarious" best described physicists and least the biologists (Woolnough, 1995, p. 60).

One may thus hypothesise that different science subjects will attract different types of students, and that the hypothesised sequence of causality from subject choice to scientific literacy may well be preceded by factors related to an individual's personality and psychological disposition. However, the actual effects of personality type and psychological profile on scientific literacy appear to be unknown, and as far as can be ascertained no studies investigating these effects exist for the South African, or any other country-specific, context. The issues with respect to the potential interrelatedness between personality, psychological profile, subject choice and scientific literacy require further examination and provide directions for further research.

*The similar effect of Biology and Geography on scientific literacy*

The level of scientific literacy - as measured by the TBSL - of students who took Biology and Biology together with Geography in matric were earlier found to be not statistically significantly different for any population group. This result suggests very strongly that the effect of Geography on scientific literacy is similar to that of Biology. In order to clarify this conclusion, the effect of Geography on the students' scores on the TBSL was investigated in a similar manner as in the case of Biology and Physical Science above. The mean score ( $\pm SD$ ) of the 77 students who included Geography but not Biology or Physical Science in their science subject combination was 12.4 ( $\pm 3.9$ ), 40.6 ( $\pm 11.8$ ), and 9.0 ( $\pm 3.5$ ) for the NSST, SCKST, and ISTSST, respectively. Although Geography students consistently displayed somewhat higher scores than Biology students on all three subtests of the TBSL, there were no statistically significant differences between the mean scores of the two groups of students (unpublished data). Students who took Geography also did not have significantly different scores than students in the control group (unpublished data). As in the case of Biology, the increase in mean score as a result of taking Geography did not push the students' score over the performance standard on any of the subtests of the TBSL.

Although I am unable to fully account for the similar performance of students taking Biology and Geography, it is speculated that similar factors to the ones believed to account for the difference between Biology and Physical Science students may be relevant here as well. Firstly, the teaching of topics covered in the South African Geography syllabus from a historical perspective may be as limited for this subject as for Biology, resulting in approximately similar scores for Geography and Biology students on the NSST. Secondly, the comparative lack of obvious technology-related topics in the South African Geography syllabus is likely to be as limiting to Geography students as to Biology students, again resulting in broadly equivalent scores on the ISTSST for both groups of students.

Thirdly, items in the biological and health sciences make up 22% and 17% of all TBSL items, respectively, whereas items in the earth and space sciences only constitute 14% of the TBSL (Chapter 5, Table 5.2, p. 96). Geography students may, however, not be as disadvantaged by the large proportion of items in the biological and health sciences as the unequal proportion of items may suggest. The nature of the concepts covered in Geography is frequently environmental in nature (e.g., ecological processes, human impact on the ecosystem, significance of oceans, etc.). As many of the concepts addressed in the content area of the biological sciences in the SCKST are also of an environmental nature, the similarity may make it possible for Geography students to answer many of the test-items in the biological and health sciences correctly. For the test-items in the physical and chemical sciences, however, exposure to formal education in these content areas is believed to be a distinct advantage. Geography students are

consequently expected to have answered correctly a similar proportion of test-items in the physical and chemical, as well as the biological and health sciences, as Biology students. Converting mean score to a percentage, Geography and Biology students correctly answered 49% and 46% of the 14 test-items in the physical and chemical sciences, respectively. The percentage of items answered correctly for the 43 items in the biological and health sciences was 57% and 60% for the former and latter group, respectively. The percentages of correctly answered test-items thus broadly fit the hypothesised pattern. Although mean scores for Geography and Biology students for each group of sciences were not statistically significantly different (in each comparison the  $p$ -value was greater than 0.05), these results provide support for a hypothesised explanation that accounts for the fact that students who took Geography as a science subject in matric had similar scores on the SCKST to students who took Biology. The above three hypothesised reasons also provide further directions for research on why the effect on the scientific literacy of students - as measured by the TBSL - of taking Geography and Biology in matric is similar and not necessarily additive.

### *The high level of scientific literacy of Engineering students*

In this study, Engineering students were consistently found to possess the highest level of scientific literacy of students in any area of subject specialisation, both within institutions and overall. It is therefore of interest to establish which factors distinguish these students from their less scientifically literate peers, and in this manner to attempt to identify factors which may have an important influence on scientific literacy. It is assumed that the scientific literacy of students is influenced by a number of different variables that interact with one another in a complex manner. In the absence of a multivariate context in which one or more such variables can be controlled, it is only possible to describe differences in the students profiles with respect to a limited number of variables that are believed to be of potential relevance in the development of scientific literacy. Theoretical considerations lead one to conclude that such variables would need to include aspects of the student's home environment, school, and interests. Examples of these variables include the number of parents with science-related occupations, a school-holiday job related to science, the choice of science subjects taken in matric, and participation in science clubs and science fairs. Each of these variables will now be discussed in turn.

Fifty-seven percent of Engineering students come from a home in which one or both parents have an occupation that is directly related to science, engineering, medicine, or technology, compared to 46% of students of other disciplines. Engineering students have a statistically significantly higher proportion of parents with a science-related occupation than other students (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ). In a general sense, this result implies that Engineering students were very probably more exposed to science than non-Engineering students. However, neither fathers ( $\chi^2 = 1.09$ , d.f. = 4,

$p > 0.05$ ) nor mothers ( $\chi^2 = 9.46$ , d.f. = 4,  $p > 0.05$ ) of Engineering students have significantly different proportions of science-related occupations in specific areas compared with the parents of non-Engineering students. The absence of any relationship between occupations in broad fields of science (i.e., pure science, engineering, medicine, or technology) and parents of different students groups indicates that there are only quantitative but not qualitative differences in the influence of science-related occupations of parents of Engineering and non-Engineering students.

It is likely that parents with a science-related occupation have a positive effect on the attitude toward science that their children develop. It is reasonable to believe that in such homes the chance is greater that books, meal-time and other conversations, as well as parental interests revolve around science (in its broadest sense) more often than in other homes. Children of such 'science parents' are thus likely to have a potentially greater interest in science, and may well have a more extensive body of knowledge of scientific concepts than children who do not come from such 'scientific homes'. In addition, it is probable that parents with a science-related occupation may be more aware of the importance of taking science subjects in senior secondary school in terms of, for example, career choice. Consequently, these parents' expectations with regard to their children's performance in science at school, and their support and encouragement of their children's efforts in science, may be higher and more extensive than for parents who do not have a science-related occupation.

Support for this argument comes from the analysis of the parental encouragement scale for Engineering and non-Engineering students. This scale is the sum of six items, namely "My parents: a) insisted I do my school homework; b) expected me to do well in science at school; c) think that science is a very important subject; d) would like me to have a career in science, medicine, or engineering; e) always encouraged me to go to a university, technikon, or college; f) know a lot about science" (Chapter 5, p. 94). A statistically significantly greater proportion of Engineering students (55%) than other students (31%) had a score of four or greater on this six-point scale (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ), suggesting that the parents of engineering students indeed exercised a greater 'science push'. This conclusion is in agreement with results from the 1987 Longitudinal Study of American Youth (Miller et al., 1990), where a structural equation model of the relative influence of a variety of family, school, and peer influences on student achievement in science was constructed. In that model, parent science push - measured using three items very similar to the six above - had a significant total effect on twelfth grade science achievement (Pifer, 1995).

The greater exposure to science of Engineering students also extended to jobs during school holidays. Thirty percent of Engineering students had a holiday job related to science, engineering, medicine, or technology, compared with 14% of students in other areas of subject specialisation; the former proportion is significantly higher than the latter proportion (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ), and suggests that a considerable number of Engineering students had some experience of

science in the workplace. It is reasonable to believe that students who held a science-related holiday job at some stage during high-school are likely to have a much more accurate view of what scientists do, and how they go about their work, than students who did not have such a holiday job. Moreover, it is possible that the students with a science-related holiday job may have experienced the application of some theories and science knowledge learned in the classroom. It is thus conceivable that the student's attitude toward, and interest in, science may have been positively influenced through the interaction with scientists, and other workers in the sciences, at the scientists' place of work.

There was a significant difference in the choice of science subjects taken in matric by Engineering and non-Engineering students ( $\chi^2 = 340.69$ , d.f. = 8,  $p < 0.001$ ). Further analysis revealed that in comparison with non-Engineering students, a significantly greater proportion of Engineering students took science subject combinations that included Physical Science (Fisher's Exact Test [ $p < 0.00001$ ]). The proportion of students who took Physical Science was more than 40% larger for Engineering students (96%) than for students in other areas of subject specialisation (67%), and the important role of this subject in scientific literacy has been addressed in the previous section (see above).

For both Engineering and non-Engineering students the proportion of students who were members of science clubs at school was generally small, the proportions being 18% and 12% for the former and latter group, respectively. Although the group of Engineering students included a statistically significantly larger proportion of science club members compared with students in other subject disciplines (Fisher's Exact Test [one-tailed],  $p < 0.00001$ ), the difference in proportions is relatively small so that differences in science club membership are likely to be of limited explanatory value with respect to levels of scientific literacy in the Engineering/non-Engineering comparison. It is interesting to note that the proportion of engineering students who had participated in at least one science fair in senior secondary school was statistically significantly *smaller* than the proportion of students in other subject disciplines (Fisher's Exact Test [one-tailed],  $p < 0.05$ ). However, once again the actual proportions of both groups were relatively similar (the proportions being 40% and 45% for the former and latter group, respectively), so that differences in science fair participation between engineering and non-engineering students are also likely to be of limited explanatory value with respect to levels of scientific literacy.

In summary it is hypothesised that a student's interest in science, positive attitude toward science, and involvement with science-related issues on a relatively regular basis is likely to impact the student's level of scientific literacy positively. On the basis of analyses of some variables that distinguish Engineering students from students in other disciplines, it appears as if the high level of scientific literacy of Engineering students is likely to be attributable to the students' greater degree of exposure to, and involvement in, a culture of science compared with that of students of other disciplines. Furthermore, results suggest that Engineering students have experienced greater parental encouragement and support than other students for taking science subjects at school.

### *Scientific literacy levels of different population groups*

One of the most consistent patterns in the analysis of levels of scientific literacy in this study was the hierarchy of results for different population groups for almost any category of additional explanatory variables. Generally speaking, levels of scientific literacy were highest for White or Indian students followed by Coloured students; African students consistently displayed the lowest levels of scientific literacy. Possible explanations for this pattern are sought among two main areas of influence widely acknowledged to affect students' general achievement: the school environment and the home environment. South African education statistics for the various population groups - where possible<sup>4</sup> - will be used to describe the former. The latter environment will be described by using the students' responses to relevant questions in the scientific literacy survey itself. This distinction was made because student responses collected in the survey on school environment were focused on science subjects only. However, as will become evident, there are profound differences (i.e., macro issues) in the quality of the school environment of different population groups which affect the schooling of pupils in more fundamental ways than the specific elements of school environment (i.e., micro issues) which were investigated with respect to the natural sciences.

#### *School environment*

For a number of reasons, students participating in this survey were required to have matriculated no more than two years prior to entering tertiary education, that is in 1993 or 1992 (Chapter 5). Assuming that students did not have to repeat a standard because of failing (a somewhat tenuous assumption in the light of the high repetition rates for African students on a national basis), a large proportion of the students included in the sample were in the senior secondary phase (i.e., Stds 8 to 10 [years 10 to 12]) between 1990 and 1993. It is thus largely for these years that education statistics will be considered, as these years have a direct bearing on the high-school experiences of the students.

On a comparative basis, the per capita expenditure on school education for various population groups in South Africa is very revealing. During 1990-93, the amount spent per head on African education ranged between 31% and 44% of that spent on White education (South African Institute of Race Relations [SAIRR], 1995). Per capita expenditure figures during the same period for Coloured pupils ranged between 59% and 74%, and for Indian pupils between 75% and 100% of that of White pupils (SAIRR, 1995). As these figures refer to primary as well as secondary education, and as about two out of every three pupils are at the primary level, these figures need to be interpreted with caution.

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4. Due to the fragmentation of the South African education system because of previous apartheid policies - 18 education departments existed in the period before 1994 (Chapter 1) - reliable overall statistics on education in South Africa are notoriously difficult to obtain (e.g., Hartshorne, 1988/9).

Nevertheless, it is abundantly clear that public expenditure for school education in South Africa was historically massively inequitable, with the education of African and Coloured pupils being financially least supported. Resource provision for the various population groups reflects this unequal distribution of funds. Whereas the number of pupils per classroom for the period 1990-1992 was 48:1 for African students, pupil-classroom ratios were about 25:1 and 28:1 for Coloured and Indian pupils, respectively (SAIRR, 1995). (Figures for White pupils for these years are unfortunately not available.) Pupil-teacher ratios similarly paint a telling picture. In 1993, there were 18.0 pupils for every teacher in White schools, compared to pupil-teacher ratios of 21.9:1 for Indian schools, and 22.2:1 for Coloured schools (SAIRR, 1994). The national average for African schools under the Department of Education and Training in the same year was 44.4:1, but ratios varied for African schools in the 'independent' and self-governing homelands between 32:1 in Venda and 51.2:1 in Transkei (SAIRR, 1994). Although these figures again need to be interpreted with caution as the ratios are averaged over primary and secondary schools, consequently yielding somewhat higher pupil-teacher ratios than those actually experienced in high-schools, the differential provision of education and, by implication, the quality of education received by pupils of different population groups becomes very apparent.

**Table 6.11.** The relative proportion (%) of teachers of different population groups with different levels of teaching qualifications in 1990 (from Table 4, EduSource, 1993).

	Unqualified		Underqualified		Qualified
	no Std 10	Std 10	no Std 10	Std 10	
African	4.0	7.5	18.3	33.2	37.0
Coloured	1.1	1.2	13.0	25.7	59.0
Indian	< 0.05	< 0.05	0.9	0.8	98.2
White	< 0.01	< 0.03	< 0.005	1.7	98.2

In any school and classroom environment the teacher plays a central role, and teacher qualification is therefore of critical relevance to the success and effectiveness of the school system. In previous years, Black teachers could obtain teaching qualifications with a Std 6 or a Std 8 pass (i.e., successful completion of year 8 or 10) followed by a two- or three-year teacher training diploma at a college of education (Siebörger & Kenyon, 1992). Since 1983, however, the minimum qualification level required of all teachers is a Std 10 pass with at least three years of appropriate training at a teacher training college (i.e., college of education), or a degree course and a one-year teaching diploma (SAIRR, 1993). If the current official minimum teaching qualification level is used as a point of reference, then teachers without any years of appropriate teacher training must be regarded as unqualified, and teachers with only one or two years of appropriate teacher training can be regarded as underqualified. Using, for example,

the 312 026 teachers in 1990 for whom internal departmental categories related to qualification level are available (Table 4 of EduSource, 1993), differences in teaching (i.e., professional) qualifications between teachers of different population groups become very evident. Whereas 98% of all Indian and White teachers in 1990 were qualified, only 59% of Coloured and 37% of African teachers met the minimum qualification level (Table 6.11). Although the percentage of African and Coloured teachers with neither a Std 10 nor a teaching qualification was comparatively low, approximately 12% of African and 2% of Coloured teachers had no teaching qualification whatsoever (Table 6.11). In contrast, virtually no Indian and White teachers were unqualified (Table 6.11). The following breakdown of the data indicates the enormous deficits in academic and professional training of African and Coloured teachers: 22% of African and 14% of Coloured teachers did not have a Std 10 (i.e., academic) qualification, compared with under 1% of Indian and White teachers. Whereas 51% of African and 39% of Coloured teachers did not have three years of teacher training, only 2% of Indian and White teachers were underqualified (Table 6.11). In general, therefore, the qualification levels of teachers in 1990 exhibit a by now familiar hierarchical pattern: virtually all Indian and White teachers met minimum qualification levels, whereas a large proportion of Coloured, and particularly African, teachers were un- or underqualified. However, no distinction was made between primary and secondary teachers in the qualification data presented above, and the data may thus potentially outline a less favourable situation with respect to qualification levels of Black secondary teachers than is actually the case. Despite this limitation, the qualification data nevertheless can only indicate that African, and to a lesser extent Coloured, pupils were being taught by poorly qualified teachers - a situation which is in stark contrast to that of Indian and White pupils.

A comparison of the qualification of African secondary school teachers in science subjects is also very revealing. General Science is a compulsory subject in all schools at the junior secondary level (i.e., Std 6 and 7 [year 8 and 9]), with the subject content being a combination of the physical and biological sciences. In Stds 8 to 10, Physical Science and Biology are taught as separate, optional subjects. In 1992, only 20% of African teachers of General Science in the Department of Education and Training (DET) were qualified, and four out of five African teachers of this subject were either not at all or underqualified (EduSource, 1993). For the same year, only 48% of African teachers of Physical Science were qualified to teach this subject (EduSource, 1993). For Biology, 1992 figures for DET teachers were not available, and 1994 figures for all African teachers (i.e., teachers in DET as well as in the former 'independent' and self-governing homelands) are used. Twenty-eight percent of African Biology teachers were unqualified, 5% were underqualified, and 67% were qualified (EduSource, 1995). In 1994, about two thirds of all African teachers of Physical Science and Biology, and 73% of all African teachers of General Science, had less than six years experience in teaching the subject, respectively (EduSource, 1995). The situation with respect to the sciences at school for African pupils was, therefore, bleak. Not only were pupils who decided to take a science subject in senior secondary phase taught by poorly



qualified and relatively inexperienced teachers, but the science was based on a foundation that was taught in junior secondary school by largely un- or underqualified teachers!

In addition, Black secondary schooling, particularly in urban areas, began to collapse as schools increasingly became the site of the struggle for political power. As the periods of student protest and revolt continued and intensified after the 1976 Soweto uprising (Kane-Berman, 1978), learning environments at Black high-schools gradually began to crumble and then disintegrate from 1988 onwards (Hartshorne, 1992). In the years 1990 to 1993, Black schools were disrupted by student and teacher protests, boycotts, stay-aways, mass action protests and marches, as well as by disputes about conditions of service for teachers which often resulted in 'chalkdowns' or suspension of classes (SAIRR, 1990, 1992, 1993, 1994). These activities had enormous implications for the number of school days devoted to teaching. In 1990, for example, the number of school days lost by DET schools in the first two terms of the year was estimated to be an average of 21 days out of a possible 96 (Hartshorne, 1992). By August 1993, DET schools had lost the equivalent of one term for that school year as a result of boycotts and teacher strikes (SAIRR, 1994). In general, African pupils were clearly worst effected, but Coloured, and to a lesser extent, Indian students did not escape the deteriorating conditions (SAIRR, 1992, 1993, 1994). In the late 1980s and early 1990s, the general learning environment of Black students, but particularly of African students, was thus characterised by haphazard and irregular school attendance, demotivated and 'burnt-out' teachers, and unsettled conditions in which violence and intimidation were rife (Hartshorne, 1992).

The general situation in Black schools during these years is in stark contrast to that of White schools, which - as far as can be ascertained - were largely unaffected by the massive crisis in Black education. None of the annual reports of the South African Institute of Race Relations, on which the above accounts of school disruptions are largely based, contain reports of disturbances at White schools (see SAIRR, 1990, 1992, 1993, 1994). As far as can be determined, schooling at these schools continued normally and was conducted in relatively well-appointed classrooms by teachers the majority of whom were motivated and well-qualified, and who worked under conditions that were orderly and comparatively stress-free.

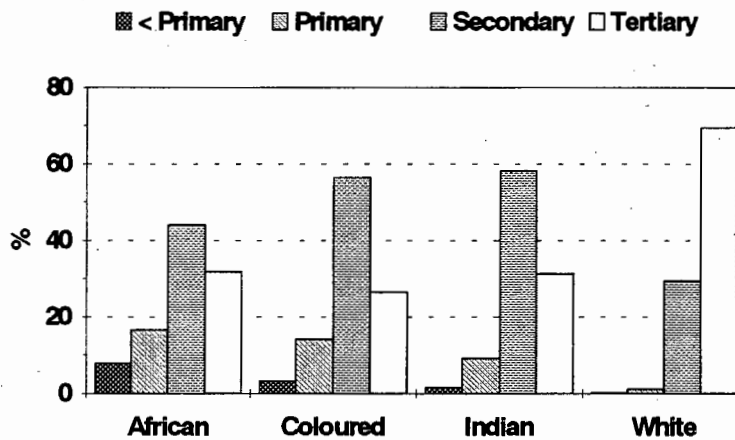
What has been described in the last few paragraphs is, to use Hartshorne's (1988/9) words, the hierarchy of inequality and discrimination in South African education. The 'pecking order', as Hartshorne described this hierarchy, is almost always White, Indian, Coloured and African - whatever recognised education criterion is used: per capita expenditure on education, pupil-classroom and pupil-teacher ratios, qualification of teachers, general learning environment. In light of the generally impoverished and frequently chaotic learning environments of Black students, it is not unreasonable to believe that the quality and effectiveness of the education provided to these students would reflect these environments. It is thus postulated that overall levels of scientific literacy of different population groups appear to reflect the 'pecking order' in the historical provision of South African education. Support for

this conclusion is evident from the results of analyses of explanatory variables with respect to scientific literacy described earlier in which the various population groups were used as categories. The pattern of levels of scientific literacy for each population group within these variables (i.e., area of subject specialisation, age, number of science subjects, and science subject combination) conform - with minor deviations for which further explanations exist - to the hierarchy of inequality in education (Tables 6.3, 6.5, 6.8, and 6.9).

The school environment is, however, only one of the two main areas of influence which impact students' achievement in school. The second area, namely home environment, is considered below.

### *Home environment*

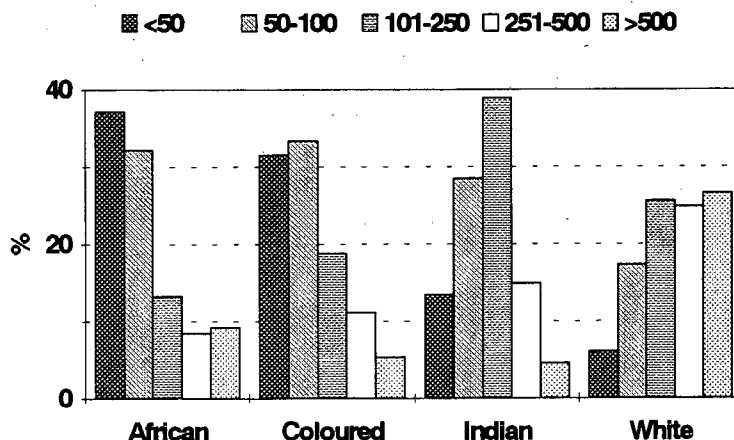
The environment in the home has been shown to be an extremely important factor influencing educational outcomes in general, and science achievement in particular (e.g., Jubber, 1994; Kremer & Walberg, 1981; Marjoribanks, 1994; Peng & Wright, 1994; Reynolds & Lee, 1991; Reynolds & Walberg, 1992). Five indicators of the prevailing home environment believed to be relevant to this study were the level of educational attainment of parents, the estimated number of books and the number of academic resources available in the home, parental encouragement for school-related work and science, and family structure (see, for example, Keeves, 1972; Reynolds & Lee, 1991). These variables are now examined in turn with respect to students of different population groups. Sample sizes of cases differed for individual variables and varied for African (max.  $n = 585$ , min.  $n = 435$ ), Coloured (max.  $n = 1090$ , min.  $n = 1044$ ), Indian (max.  $n = 67$ , min.  $n = 66$ ), and White (max.  $n = 2467$ , min.  $n = 2091$ ) students.



**Figure 6.1.** The proportion (%) of parents of different population groups with completed primary, secondary, or tertiary education qualifications as the highest level of educational attainment.

Levels of educational attainment were established from data on the highest level of education completed by the parents of students (Chapter 5, Table 5.1, pp. 90-92). Completion of primary and secondary school (i.e., completion of Std 5 and 10), and a first qualification from a university, technikon, teacher training or nursing college were taken to indicate educational attainment at the primary, secondary, and tertiary education level, respectively. The highest level of either parent was used. Levels of highest educational attainment for parents of students of different population groups are presented in Figure 6.1.

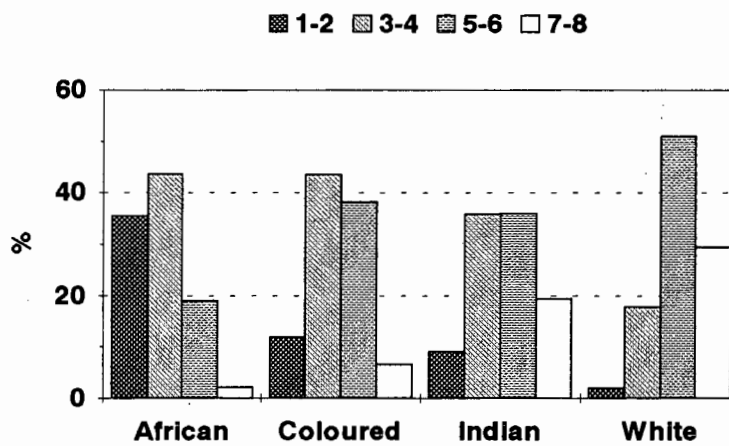
A similar proportion of African, Coloured, and Indian parents have as their highest level of educational attainment a tertiary education qualification. However, a smaller proportion of African parents have a secondary qualification compared with Coloured and Indian parents (Figure 6.1). Out of all students, African students have proportionally the greatest number of parents who have as their highest level of educational attainment a primary education qualification or less. On the other hand, the vast majority of White parents have completed secondary school and about 70% have gone on to obtain a tertiary education qualification (Figure 6.1). Overall, therefore, African and White parents have the lowest and highest levels of educational attainment, respectively, with the level of Coloured and Indian parents located in-between the level of African and White parents.



**Figure 6.2.** The distribution of the estimated number of books available in the homes of students of different population groups.

The patterns in parental levels of educational attainment described above are notable because they broadly reflect the hierarchy of discrimination in South Africa amongst adults due to previous apartheid policies. Moreover, the differences in parental levels of education suggest that there are, as a consequence, very likely to be differences in the home environment of students of different population

groups. Different levels of educational attainment are believed to influence achievement in at least two ways. Firstly, high levels of education imply that parents are likely to possess appropriate knowledge, attitudes, values, and skills that can have an influence on their child's education (Hushak, 1977; Jubber, 1994). For example, it is argued that highly educated parents possess more skills that they can teach their children than less well educated parents (Hushak, 1977). Although Hushak (1977) formulated this argument in a primary school context, there is evidence that his argument is also applicable in a setting of secondary schooling. For example, in a South African study on the association between mother's level of education and the school performance of 471 pupils in Std 9 (year 11), du Plooy (1988) found that the average academic performance of pupils with mothers who possess post-matric qualifications was significantly higher than that of pupils whose mothers were less educationally qualified. Similarly Jubber (1994), in a longitudinal study of 174 White pupils in Cape Town, reported statistically significant associations between school performance in Std 10 and both the mother's and father's level of education.

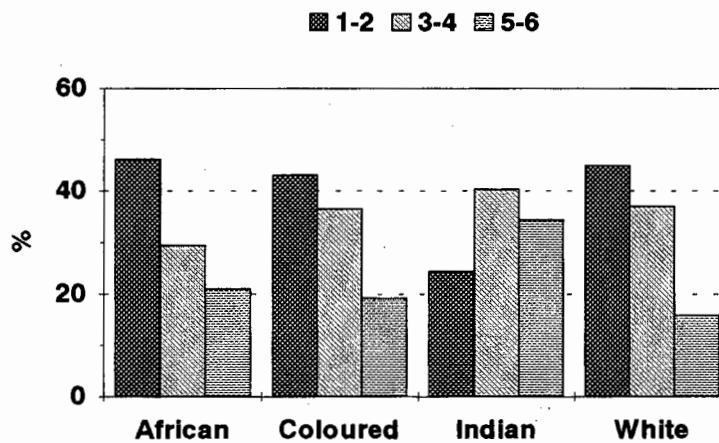


**Figure 6.3.** The proportion (%) of homes of students of different population groups with different numbers of academic home resources.

Secondly, it is reasonable to believe that the level of educational attainment of parents influences the economic status of the family, and consequently the educational resources available to their children. As Jubber (1994, p. 137) has argued: "wealth affords many educationally relevant advantages ... wealth enables families to provide the books and other resources necessary for successful study as well as the means to give the child the privacy, quiet and comfort that facilitates serious study". The parental level of educational attainment is therefore likely to affect the resources (see Reynolds & Lee, 1991) that are made available by parents to their children. It can thus be hypothesised that a home with a higher number of material, behavioural, and psychological resources will constitute an educationally more conducive

home environment compared to a home with fewer such resources. What follows is an examination of examples of such resources (i.e., the number of books, the number of academic home resources, and parental encouragement) for students of different population groups who participated in the scientific literacy survey.

The extent of the private library in the home was estimated in five categories of increasing number of books by the students (Chapter 5). For African and Coloured homes, the frequency of smaller categories was predominant, for Indian homes the frequency distribution of categories was bell-shaped, and for White homes the frequency of large categories was dominant (Figure 6.2). There is thus a clear trend of



**Figure 6.4.** The frequency distribution of scores on the six-point parental encouragement scale for students of different population groups.

an increasingly larger stock of books being available as one moves along population group categories from African to White homes. Eight different academic home resources were listed in the survey questionnaire, and students were asked to state whether each resource was present in their homes (Chapter 5, Table 5.1, pp. 90-92). Results show that in African homes four academic resources were commonly present, in Coloured and Indian homes three to six resources were usually available, and in White homes five to eight academic resources were generally present (Figure 6.3). The frequency distribution of the number of academic resources present in homes is thus ordered with respect to population groups, with the homes of African students having the least number of resources available, and the homes of White students the most resources available. In general, therefore, the number of material resources - as measured by the examples used here - appear to reflect the pattern of levels of educational attainment with respect to population group observed immediately above.

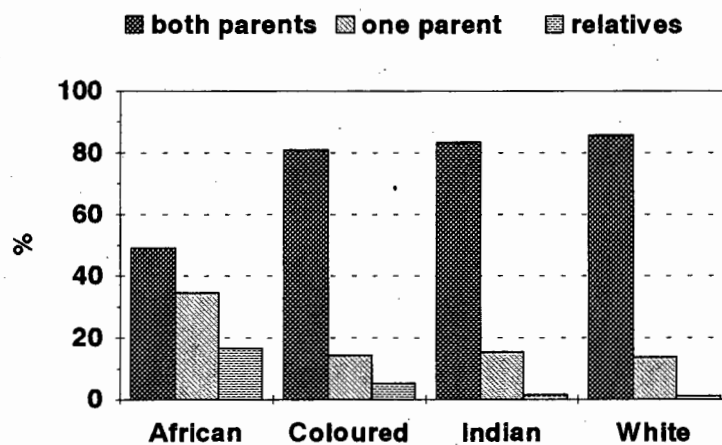
The six-point self-reported parental encouragement scale is a combination of items related to parental support of and knowledge about science, and also consists of items related to parental expectations for their children's educational attainment and parental support for school-related work in general and in science in particular (see above). Scores on this scale were grouped into two-point categories, and the frequency distribution of these categories is given in Figure 6.4. Interestingly, the score distributions of African, Coloured, and White students were broadly similar. In 75% to 80% of cases for students of these population groups, the score on the parental encouragement scale was between one and four, whereas in about 75% of cases for Indian students the score was between three and six (Figure 6.4). Parents of Indian students therefore appear to be more encouraging than parents of students of other population groups when it comes to homework, school science, and career expectations for their children. This comparatively high 'parent science push' may be a particular reason why Indian students display high levels of scientific literacy.

In general, however, the patterns in the distribution of scores on the parental encouragement scale for different population groups do not conform to patterns with respect to levels of educational attainment described earlier. Two explanations are possible; one is more specific, and the other is more general in scope. Firstly, the absence of conformity of trends may indicate that parents with higher levels of educational attainment do not view science as being of greater importance to their children's education than parents of lower levels of educational attainment. Secondly, the finding may suggest that behavioural and psychological resources provided by parents - as measured in this study - do not necessarily reflect the parents' economic status, as the provision of these two types of resources is less dependent on income level than the provision of material resources. For example, Hess and Holloway (1984, cited in Kurdek & Sinclair, 1988) were able to demonstrate links between parental values and academic achievement, and there is evidence that suggests that success in school among poor children is related to deliberate efforts on the part of parents to inculcate discipline and good study habits in their children (Clark, 1983; cited in Astone & McLanahan, 1991). The kind of behavioural and psychological resources parents provide for their children is thus probably as dependent on their attitude towards, and expectations for, their children's education as on the level of affluence of the parents.

It is generally recognised that family configurations that differ from the two-parent, intact family are frequently associated with less favourable educational outcomes of children (see, for example, Marsh, 1990). Empirical research provides reasonably consistent evidence that children from single-parent families obtain lower achievement test-scores and end-of-year marks than children from nuclear families (e.g., Kurdek & Sinclair, 1988; Marsh, 1990; Mulkey, Crain, & Harrington, 1992; Zimiles & Lee, 1991). Although there is consistent evidence that the effects of family structure on student achievement are statistically significant but slight once other family background variables (e.g., socio-economic status, race, gender, etc.) have been controlled, there is also a recognition that much of the recent

empirical evidence in this area reflects family configurations in the United States in the 1980s, and that "it is possible, even likely, that the conclusions would not be the same in a different society or a different point in history" (Marsh, 1990, p. 337).

In view of these findings, the family structure of students from different population groups was examined. In the survey questionnaire, students were asked to indicate whether in the last two years of high-school (i.e., in Std 9 and 10) they lived with both parents, with only one parent (either mother or father), with a relative, or in boarding school (Chapter 5). (Students who reported that they lived in boarding school were excluded from the analysis, as they could come from any of the above family configurations.) The results of the analysis of the family structure of students of different population groups are presented in Figure 6.5. Whereas more than 80% of Coloured, Indian, and White students lived with both parents, only about 50% of African students did so. Approximately 35% of students in the latter group lived with only one parent, compared to about 14% of students in the former group. The proportion of African students who lived with relatives was also much higher than for students of other population groups, particularly for Indian and White students (Figure 6.5).



**Figure 6.5.** The proportion of students of different population groups who lived with both parents, with only one parent (mother or father), or with a relative during the last two years of secondary school.

These findings indicate that family configuration of Coloured, Indian, and White students is very similar, and essentially differs only in the proportion of students who lived with a relative. The great majority of students in these population groups come from two-parent, intact families, which is in stark contrast to African students where single parents (in over 90% of cases involving the mother rather than the father) and relatives play a major role in the composition of family configuration. The proportions of Coloured, Indian, and White students from an intact family hardly differ from each other yet students

from these population groups display substantially different overall levels of scientific literacy (Table 6.1). In fact, a chi-square analysis of the  $2 \times 2$  contingency table for a combined group of Coloured, Indian, and White students revealed that scientific literacy was independent of family structure ( $\chi^2 = 0.65$ ,  $p > 0.05$ ). Despite the fact that African students had a distinctly different profile of family configuration to students from other population groups, a similar analysis showed that scientific literacy was also independent of family structure for this population group ( $\chi^2 = 0.068$ ,  $p > 0.05$ ).<sup>5</sup> (It is widely accepted that single parent households and absentee parents are common in African communities primarily because of the existence of a migrant labour system in South Africa [e.g., Wilson & Ramphele, 1989]. I am, however, unable to identify African students whose home environment is likely to have been affected by such circumstances.) The above results suggest that family configuration does not influence the scientific literacy of 'successful' school leavers (i.e., students who have gained admission to tertiary education) for all four population groups. This finding may potentially support conclusions from other studies which reported that family structure had little effect on school performance in the last two years of high school (Jubber, 1994; Marsh, 1990).

The investigation of family structure concludes the analysis of the home environment of students participating in the scientific literacy survey. A number of qualitative differences with respect to population group were observed in the five variables believed to have an impact on home environment, and these differences are summarised in Table 6.12. Levels of educational attainment were lowest for African and highest for White parents. Differences in these levels led to a number of hypothesised patterns for three of the four other variables related to the prevailing home environment of students at the time the students were in the senior-secondary phase. Overall, findings indicated that material (i.e., academic) resources provided for students by parents in Black homes are substantially fewer than in White homes. Furthermore, the number of material resources provided within Black homes was found to be smallest in African homes. The provision of behavioural and psychological resources (i.e., scores on the parental encouragement scale) appeared to differ between homes of Indian students on the one hand, and homes of students from other population groups on the other. Although a major difference was observed in the family structure of African students compared with that of students from other population groups, scientific literacy was found to be independent of family configuration for all population groups. In general, there is therefore evidence that the home environment of African, Coloured, Indian, and White students is qualitatively different. There is therefore some support for the conjecture that the home environment of African students is educationally less conducive than that of White students. Findings suggest that Coloured homes appear to be educationally more conducive than African homes, but are likely to be less so than White homes. Indian students experienced a significantly greater 'parent science

5. But see Chapter 7 (p. 176), where the association between family structure and scientific literacy is investigated in a multivariate context and where, as a consequence, different conclusions are reached.



push' than students of other population groups, and the homes of Indian students also appeared to be closest to White homes in terms of educational conduciveness.

**Table 6.12.** A summary of the qualitative differences with respect to population group in variables believed to have an impact on the home environment of students.

Home environment variable	African	Coloured	Indian	White
Level of educational attainment	--	-	-	++
Number of books	--	-	+	++
Number of academic resources	--	-	+	++
Parental encouragement	-	-	+	-
Family structure	-?	+	+	+

There thus seems to be evidence for the conclusion that the differences in the level of scientific literacy displayed by students of different population groups are likely to be the consequence of both differential school and differential home environments experienced by African, Coloured, Indian, and White students.

### *Levels of scientific literacy of matriculants - what do they tell us?*

Levels of scientific literacy attained by matriculants in this survey are essentially not comparable with the findings of surveys from other countries for a number of reasons. Firstly, although the development of the TBSL was based on the research framework of Miller, Durant and their colleagues, the TBSL takes a different, essentially complementary, approach to measuring scientific literacy (Chapter 4). The relatively small number of items with unspecified content validity used in other surveys has been replaced in the TBSL by a larger set of test-items based on *Science for all Americans* (Chapter 4). Secondly, locally-set performance standards were used for all three dimensions of scientific literacy measured by the TBSL. In contrast to previous studies, there thus exist threshold levels for the scores on the three subtests of the TBSL which need to be met or exceeded in order for individuals to be classified as scientifically literate (Chapter 4). Latest national and cross-national surveys no longer combine the separate indices for the three 'constitutive dimensions' of scientific literacy into an overall indicator (see, for example, BIE, 1995; INRA [Europe] & Report International, 1993; NSB, 1993) - as was the practice in earlier surveys (e.g., Miller, 1989b) and as is done in this study - but report attainment levels on each dimension separately. This reporting usually takes the form of mean scores for a specific combination of questions, and percentages of respondents who reported particular interests or answered specific questions correctly. Thirdly, previous studies conducted surveys of scientific literacy among the general adult

population, whereas the current study focuses only on young adults at the secondary/tertiary education interface. Moreover, as the current method of measuring scientific literacy is novel, no other surveys have as yet employed this approach, and hence no precedents for comparisons exist at this stage, either in South Africa or elsewhere.

In order to make an assessment of the ability of current South African high-school science education to generate scientifically literate high-school leavers, it was believed to be appropriate to examine the output of the education system, that is matriculants. Such individuals will have taken at least one science subject (i.e., General Science) up to Std. 7 (grade 9), as required by law.<sup>6</sup> Moreover, by definition, all matriculants have passed the matric exam and must therefore be regarded as successful products of the education system. The obvious question as to whether the levels of scientific literacy of matriculants of different population groups are acceptable or satisfactory cannot at this point be answered in any rational manner, as in the absence of any comparative data this is a value-laden question, with no defensible, objective manner available for deciding on that value. Overall levels of scientific literacy must, therefore, be essentially regarded at this stage as observations. Nevertheless, these observations form important baseline data with respect to the prevailing levels of scientific literacy of matriculants entering tertiary education in immediate post-apartheid South Africa, against which the impact of future policies in education can be measured.

Until levels of scientific literacy amongst *all* matriculants, and not only amongst those entering tertiary education, are estimated, an appraisal of the ability of the South African education system as a whole to produce scientifically literate high-school leavers must remain largely speculative. Nevertheless, it is possible to derive estimates of the overall level of scientific literacy amongst all matriculants (labeled  $S$  in Equation 1) by extrapolating the data from the current survey in the Western Cape in the following manner.

At the beginning of any academic year, the total number of matriculants (i.e., a cohort of school-leavers who passed the matric exam at the end of the previous year) is essentially composed of two groups: matriculants who go on to tertiary studies at universities and technikons in that year ( $m_1$ ), and those matriculants who do not ( $m_2$ ):

$$S = s_1 m_1 + s_2 m_2. \quad (1)$$

The level of scientific literacy of all matriculants ( $S$ ) is obtained by calculating the product of the level of scientific literacy (as a proportion  $s$ ) and the number of matriculants ( $m$ ) for each of the matriculant groups (Equation 1). The two weighted values are then added (Equation 1). The number of matriculants

6. This fact was believed to represent reasonable and sufficient grounds for including the 383 matriculants who took no science subjects in *matric* in the sample used to estimate the level of scientific literacy of all matriculants (see Table 6.13).

in each group (i.e.,  $m_1$  and  $m_2$ ) can be estimated from relevant and accessible data, while the level of scientific literacy of first-time entering students at universities and technikons in the Western Cape (i.e.,  $s_1$ ) is inferred from the sample in this study (i.e., Table 6.1). The final element of the calculation (i.e., the level of scientific literacy of school-leavers not going on to studies at universities and technikons -  $s_2$ ) must currently be surmised in the absence of any data in this area. It is unlikely that the level of scientific literacy of both groups of matriculants will be similar (see below). Thus a reasonable alternative to using identical values for  $s_1$  and  $s_2$  in the calculation of the level of scientific literacy of all matriculants would be to base the estimate for  $s_2$  on different assumptions about the relative scientific literacy of both groups (i.e., on different ratios of the level of scientific literacy of those matriculants who do not go on to universities and technikons versus the level of those who do).

Values for the number of matriculants in each group (i.e.,  $m_1$  and  $m_2$ ) were obtained in the following manner. For each population group, the annual number of first-time entering students at universities and technikons in South Africa was determined for the period 1989 to 1991 from Department of National Education statistics (Department of National Education [DNE], 1992ab, 1993ab, 1994ab) - the latest available relevant national statistics. In order for the national data to conform as closely as possible to the profile of the student sample used in this study, only the number of first-time entering students who were 24-years old or younger was used. (The number of students younger than 24-years old, the age limit in the survey, could not be determined from DNE figures.) For each population group, the annual number of school-leavers with a Senior Certificate (i.e., a matric pass) for the period 1988 to 1990 was obtained from Central Statistical Services (1994). Data for the former 'independent' homelands (i.e., Transkei, Bophuthatswana, Venda, and Ciskei) were not available, and matriculants and students from these territories were therefore excluded from all calculations. Using the above data, the average number of first-time entering students at South African universities (undergraduate) and technikons (pre-diplomate) as a proportion of the number of matriculants in the previous year was calculated to be 22.0%, 36.6%, and 56.5% for African, Coloured, and White students, respectively, for the period 1989-1991. The above three proportions were then used to estimate the level of scientific literacy amongst all matriculants of each population group as described by Equation 1, given different assumptions about the ratio of the level of scientific literacy of those matriculants who do not go on to universities and technikons versus the level of those who do (Table 6.13). The sample size of Indian students ( $n = 67$ ) was believed to be inadequate for such extrapolation and Indian students were therefore not considered further. The above procedure is an attempt to provide a potentially more meaningful interpretation of the levels of scientific literacy measured in the current survey. It is intended to highlight the enormity of the challenge that the South African community must face, rather than claim a definitive overview.

**Table 6.13.** Estimated levels of scientific literacy (%) of all matriculants per population group for different relative levels of scientific literacy of matriculants not entering tertiary education versus that of matriculants who do. (Indian and former 'independent' homeland students are excluded).

Relative level (%)	African	Coloured	Indian	White
100	10	27	-	46
80	9	24	-	42
60	7	20	-	38
50	6	18	-	36
25	4	14	-	31
10	3	12	-	28
0	2	10	-	26

A number of assumptions underpin the above extrapolation from sample results. Firstly, it is assumed that the level of scientific literacy of different population groups determined for students at the five major tertiary institutions in the Western Cape is representative of students at the national level. Although the interpretation of data extrapolated from regional to national level must naturally be guarded, sample size of Coloured ( $n = 1091$ ) and White ( $n = 2470$ ) students in the Western Cape sample were appropriately large to justify and believe that the above assumption was likely to be reasonable (Chapter 5). Although African students were under-represented in the sample relative to their distribution among the first-time entering student population at the five institutions in the Western Cape, the sample size for African students ( $n = 595$ ) was nevertheless substantial. It is therefore reasonable to believe that the level of scientific literacy of African students in the sample approximates that of African students nationally.

Secondly, it is assumed that the relative number of first-time entering students per broad area of subject specialisation in the sample corresponds to the national profile of such students in these areas at South African universities and technikons. Students in the subject specialisation of Commerce and Management, and the Human Sciences, form the great majority of the sample (Chapter 5, Table 5.4, pp. 99). As it is probable that only a small proportion of students start their studies in one area but complete their degree or diploma in another area, the relative number of first-time entering students per area of subject specialisation in the sample suggests that the majority of students will complete their first tertiary educational qualification in areas other than natural sciences and engineering. This situation is in agreement with recent profiles of students graduating from universities and technikons. For the period 1984 to 1990, South African universities produced more graduates in the social sciences and humanities than in the natural sciences and engineering (FRD, 1993; Pouris, 1991a; Chapter 1). Moreover, annual

technikon graduation statistics of 1988 versus 1991 (by diploma) reveal a sharp shift away from science and engineering fields of study to those of commerce and management (Cooper, 1995).

Thirdly, it is assumed that the proportion of matriculants who go on to study at universities and technikons in the year following their matriculation is relatively stable from year to year. In order to minimise the effect of potential fluctuations, the average proportion for the different population groups for the years 1988/89, 1989/90, and 1990/91 was used. In the absence of university and technikon data more recent than for 1991, the assumption that this averaged proportion is applicable to 1993 matriculants must remain untested.

The conclusions drawn from estimated levels of scientific literacy of all matriculants (Table 6.13) depend on the assumption made about the level of scientific literacy of matriculants who do not go on to universities and technikons in the year following their matriculation. The rationale behind dividing all matriculants into a group of individuals who go on to study at universities and technikons and into another group of individuals who do not, was that the former group can be expected to have higher academic ability. Consequently, individuals in the former group are also likely to display higher levels of scientific literacy than individuals in the latter group. However, individuals in the latter group include not only matriculants who cannot enter tertiary education because of inadequate matriculation results, but also include matriculants who enter universities and technikons at a later stage, as well as matriculants who enter other tertiary institutions (such as, for example, nursing and teacher training colleges). Levels of scientific literacy of matriculants who do not go on to universities and technikons in the year following matriculation are therefore not necessarily as low as may be initially believed.

Given the inequitable provision of education between pupils of different population groups as a consequence of apartheid education, it must be assumed that only White schools can be regarded as having been normally resourced (i.e., in terms of provision of classrooms, qualified teachers, comparatively well-equipped schools, etc.). Consequently, it seems reasonable to assert that only the overall level of White students gives an indication of what the current education system is able to deliver with respect to the attainment of scientific literacy of matriculants of other population groups, given similar levels of per capita expenditure on education and similar socio-economic influences.

Based on the above extrapolation of data obtained from our sample of a highly select group of matriculants in the Western Cape, what can be said about the ability of the science education provided by the current South African education system to generate scientifically literate matriculants? As was mentioned earlier, in the absence of any comparative data from other countries, it is difficult to arrive at a defensible conclusion about what a satisfactory or acceptable level of scientific literacy for all South African matriculants would be. Conclusions must therefore necessarily rely on value judgements as to what may be regarded as satisfactory. Table 6.13 provides a spectrum of possible levels of scientific literacy of all matriculants of different population groups, each level depending on assumptions about

different levels of scientific literacy of matriculants not entering universities and technikons. The possible outcomes include both a worst-case scenario (i.e., the situation in which all matriculants not entering universities and technikons are scientifically illiterate) and a best-case scenario (i.e., the situation in which levels of scientific literacy of all matriculants are equivalent to those of students entering universities and technikons).

Although desirable and at face value tempting to strive towards, a 100% overall level of scientific literacy is unlikely to be a reasonable and practical goal, nor is this goal necessarily cost effective. Even for an education system that does not have as an explicitly stated goal the generation of scientifically literate matriculants, it would seem to be a plausible starting point to expect a substantial percentage of matriculants - say one in three - to be scientifically literate in order for the quality of science education to be rated as acceptable. It can be seen from Table 6.13 that if this criterion is applied, only the education provided to White students is likely to be regarded as acceptable, assuming that the level of scientific literacy of matriculants not going on to universities and technikons is not lower than about 25% of that of matriculants who do go on to these institutions. Even in the best-case scenario the quality of science education provided to African and Coloured matriculants does not reach an acceptable level, although results suggest that it appears to come close to that for the latter group of students (Table 6.13). If, on the other hand, it is assumed that one in two matriculants is required to be scientifically literate in order for the provision of science education to be regarded as satisfactory, no education provided to any of the population groups would merit this rating, even for very high comparative levels of scientific literacy of matriculants not going on to universities and technikons (Table 6.13).

Based on the careful extrapolation of data from a regional to a national level, and given a number of assumptions that underpin this extrapolation, it can be speculated that the ability of the recent South African education system to generate scientifically literate matriculants is likely to be generally unsatisfactory, and at best acceptable only for matriculants in the historically privileged White educational system. As students from other population groups constitute the vast majority of school-leavers in South Africa, this situation is great cause for concern.

## CONCLUSION

Post-apartheid South Africa is currently facing a challenging future, and at this important juncture in the country's history it would seem to be appropriate to take stock of the various key services provided by the state that will play an important role in South Africa's economic and social progress. Education in general, and science education in particular, is one of those crucial services. A now widely accepted goal of science education throughout the industrialised world is the generation of scientifically literate high-

school leavers, and in this exploratory study the levels of scientific literacy of first-time entering students at the five major tertiary educational institutions in the Western Cape have been determined.

In general, patterns of scientific literacy levels have been found to follow hypothesised trends. Although some general conclusions of the present survey with respect to levels of scientific literacy are not novel and have been stated before in contexts related to general science achievement, this study has confirmed generally held beliefs that variables such as, for example, the number of science subjects and the combination of science subjects taken in senior high-school, are likely to have an important impact on scientific literacy. In particular, the differential impact of taking Physical Science, Biology, and Geography, on scientific literacy - as measured by the TBSL - has been highlighted. The issues raised with respect to the influence of different science subjects on different dimensions of scientific literacy require further examination and provide directions for further research. The importance of exposure to, and involvement in, a culture of science was evident from the high levels of scientific literacy of Engineering students, who displayed the highest level of scientific literacy measured amongst first-time entering students from a variety of broad areas of subject specialisations.

The most striking, yet not unexpected, finding was that levels of scientific literacy of students from different population groups largely reflect the hierarchy of inequality due to previous apartheid policies. This hierarchy was explained in terms of the school environment of students from different population groups, as well as in terms of the student's home environment. Findings suggest that African and Coloured students are likely to come from a less educationally conducive home environment. As the majority of variables related to home environment may be regarded as essentially 'unalterable' (see Staver & Walberg, 1986), it would seem to be important to examine in greater detail variables related to the school environment (see Chapter 7). Many of the variables related to the school environment are alterable (i.e., more under the *direct* control of educators) and therefore more amenable to intervention. Although the sample size of African students was adequate, similar research needs to be repeated with larger number of African students in order to ensure that results have a sufficient degree of generality. These recommendations apply particularly to Indian students, who displayed high levels of scientific literacy but constituted only a very small group of unknown representativeness in this survey.

Based on extrapolation of the data obtained from a sample of a highly select group of matriculants from the Western Cape, it is speculated that the science education provided by the South African education system to White students may well be regarded as reasonably acceptable. However, results suggest that the science education available to African and Coloured matriculants does not reach minimally acceptable levels, even in the best-case scenario for estimates of the level of scientific literacy of matriculants not going on to further studies at universities and technikons. This situation presents an enormous challenge to science educators in South Africa, and in Chapter 8 an attempt is made to map the way forward.

2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 2162, 2163, 2164, 2165, 2166, 2167, 2168, 2169, 2170, 2171, 2172, 2173, 2174, 2175, 2176, 2177, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186, 2187, 2188, 2189, 2190, 2191, 2192, 2193, 2194, 2195, 2196, 2197, 2198, 2199, 2200, 2201, 2202, 2203, 2204, 2205, 2206, 2207, 2208, 2209, 2210, 2211, 2212, 2213, 2214, 2215, 2216, 2217, 2218, 2219, 2220, 2221, 2222, 2223, 2224, 2225, 2226, 2227, 2228, 2229, 2230, 2231, 2232, 2233, 2234, 2235, 2236, 2237, 2238, 2239, 2240, 2241, 2242, 2243, 2244, 2245, 2246, 2247, 2248, 2249, 2250, 2251, 2252, 2253, 2254, 2255, 2256, 2257, 2258, 2259, 2260, 2261, 2262, 2263, 2264, 2265, 2266, 2267, 2268, 2269, 2270, 2271, 2272, 2273, 2274, 2275, 2276, 2277, 2278, 2279, 2280, 2281, 2282, 2283, 2284, 2285, 2286, 2287, 2288, 2289, 2290, 2291, 2292, 2293, 2294, 2295, 2296, 2297, 2298, 2299, 2300, 2301, 2302, 2303, 2304, 2305, 2306, 2307, 2308, 2309, 2310, 2311, 2312, 2313, 2314, 2315, 2316, 2317, 2318, 2319, 2320, 2321, 2322, 2323, 2324, 2325, 2326, 2327, 2328, 2329, 2330, 2331, 2332, 2333, 2334, 2335, 2336, 2337, 2338, 2339, 2340, 2341, 2342, 2343, 2344, 2345, 2346, 2347, 2348, 2349, 2350, 2351, 2352, 2353, 2354, 2355, 2356, 2357, 2358, 2359, 2360, 2361, 2362, 2363, 2364, 2365, 2366, 2367, 2368, 2369, 2370, 2371, 2372, 2373, 2374, 2375, 2376, 2377, 2378, 2379, 2380, 2381, 2382, 2383, 2384, 2385, 2386, 2387, 2388, 2389, 2390, 2391, 2392, 2393, 2394, 2395, 2396, 2397, 2398, 2399, 2400, 2401, 2402, 2403, 2404, 2405, 2406, 2407, 2408, 2409, 2410, 2411, 2412, 2413, 2414, 2415, 2416, 2417, 2418, 2419, 2420, 2421, 2422, 2423, 2424, 2425, 2426, 2427, 2428, 2429, 2430, 2431, 2432, 2433, 2434, 2435, 2436, 2437, 2438, 2439, 2440, 2441, 2442, 2443, 2444, 2445, 2446, 2447, 2448, 2449, 2450, 2451, 2452, 2453, 2454, 2455, 2456, 2457, 2458, 2459, 2460, 2461, 2462, 2463, 2464, 2465, 2466, 2467, 2468, 2469, 2470, 2471, 2472, 2473, 2474, 2475, 2476, 2477, 2478, 2479, 2480, 2481, 2482, 2483, 2484, 2485, 2486, 2487, 2488, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509, 2510, 2511, 2512, 2513, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529, 2530, 2531, 2532, 2533, 2534, 2535, 2536, 2537, 2538, 2539, 2540, 2541, 2542, 2543, 2544, 2545, 2546, 2547, 2548, 2549, 2550, 2551, 2552, 2553, 2554, 2555, 2556, 2557, 2558, 2559, 2560, 2561, 2562, 2563, 2564, 2565, 2566, 2567, 2568, 2569, 2570, 2571, 2572, 2573, 2574, 2575, 2576, 2577, 2578, 2579, 2580, 2581, 2582, 2583, 2584, 2585, 2586, 2587, 2588, 2589, 2590, 2591, 2592, 2593, 2594, 2595, 2596, 2597, 2598, 2599, 2600, 2601, 2602, 2603, 2604, 2605, 2606, 2607, 2608, 2609, 2610, 2611, 2612, 2613, 2614, 2615, 2616, 2617, 2618, 2619, 2620, 2621, 2622, 2623, 2624, 2625, 2626, 2627, 2628, 2629, 2630, 2631, 2632, 2633, 2634, 2635, 2636, 2637, 2638, 2639, 2640, 2641, 2642, 2643, 2644, 2645, 2646, 2647, 2648, 2649, 2650, 2651, 2652, 2653, 2654, 2655, 2656, 2657, 2658, 2659, 2660, 2661, 2662, 2663, 2664, 2665, 2666, 2667, 2668, 2669, 2670, 2671, 2672, 2673, 2674, 2675, 2676, 2677, 2678, 2679, 2680, 2681, 26





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## Chapter Seven

# **PREDICTORS OF SCIENTIFIC LITERACY OF MATRICULANTS ENTERING MAJOR TERTIARY EDUCATIONAL INSTITUTIONS IN THE WESTERN CAPE**

### **INTRODUCTION**

South Africa faces a number of critical socio-economic challenges, in the solution of which scientific literacy is believed to be able to play an important role (Chapter 1). Addressing these challenges in a meaningful manner will almost certainly take more than a decade, and will involve today's matriculants as part of tomorrow's labour force and general public. In order to obtain a clearer picture of the scientific literacy of South African matriculants, it is appropriate to determine what are the current predictors of scientific literacy for this group, and in this manner to ascertain which student background variables appear to have the most influence on whether matriculants are scientifically literate or not. Furthermore, given the large disparity in the quality of schooling historically provided for Black and White pupils by the former segregated education departments in South Africa (see, for example, Hartshorne [1992]; Chapter 6), the detrimental effects of which are especially pronounced with respect to the natural sciences (see, for example, Blankley, 1994), we need to ask whether the predictors of scientific literacy are similar for all matriculants. These are the two research questions which this chapter attempts to answer. Answers to these questions will hopefully yield useful information for policy makers, and may identify important 'alterable' variables (Staver & Walberg, 1986), associated with scientific literacy, that educators are able to influence or manipulate, and thus change, directly.

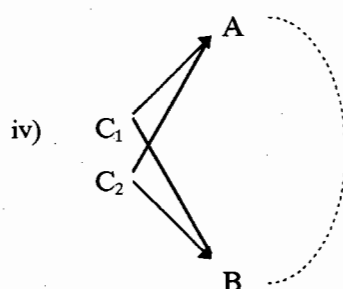
The study included data on 4227 first-year students at the five major tertiary educational institutions in the Western Cape (Chapter 5). A multivariate logistic regression model of predictors of scientific literacy was used, with the analyses being guided largely by the recommendations contained in Hosmer and Lemeshow (1989). Scientific literacy was defined as the response variable, with the various student background variables constituting the explanatory variables. The thrust of this study is the identification of associations between the response and explanatory variables, and in explaining such associations it is not unreasonable to make assumptions, or to draw conclusions, about the causality between scientific literacy and other variables. However, it needs to be noted throughout this chapter that different lines of causality are possible (Figure 7.1). For example, the line of causality between two variables may proceed in only one direction (i.e., Figure 7.1.i or 7.1.ii), or in both directions (i.e., Figure 7.1.i and 7.1.ii), and variables may be mutually causative (Figure 7.1.iii). Furthermore, it is also possible that common

causative sources exist for two variables that are otherwise independent but yet still show some degree of association (Figure 7.1.iv).

i)  $A \longrightarrow B$

ii)  $A \longleftarrow B$

iii)  $A \longrightarrow B \longrightarrow A \longrightarrow B \dots$



**Figure 7.1.** Different lines of causality between two associated variables.

The questionnaire is briefly outlined first, thereafter details of the student background variables and coding used in this study are sketched, and finally the data analysis itself is discussed.

## THE SURVEY QUESTIONNAIRE

As was described in Chapter 5, the survey questionnaire sought self-reported data on student background variables in a number of different areas: demographic, educational, and socio-economic (see Appendix G, pp. 309-330). Firstly, the questionnaire sought general student high-school details such as matriculation year, Examining authority, science subject(s) taken in senior high-school, and overall matric symbol, as well as age, gender, and home language. Secondly, the questionnaire sought retrospective data on instructional quality (emphasis and foci of instruction, classroom environment), student homework, attitudes toward science, motivation, and exposure to mass-media (science and non-science related). Thirdly, the survey questionnaire sought information on variables related to home environment such as,

for example the number of children per family, educational attainment of parents, nature and number of home resources, family structure, parental encouragement and involvement, as well as on whether parents had science-related occupations. Data on the outcome variable - scientific literacy - were provided by the 110-item *Test of Basic Scientific Literacy* (Chapter 4) which formed the second section of the survey questionnaire (see Appendix G, pp. 309-330).

### **Student background variables**

Fifty-two variables and unobservable compound variables (i.e., latent constructs) were available for modelling predictors of scientific literacy. Characteristics and descriptive statistics of these variables were given in Chapter 5 (Table 5.1, pp. 90-92) but are presented here again, together with changes in the coding of certain variables based on preliminary analyses, for the convenience of the reader (Table 7.1). Deviations from the coding of variables described in Chapter 5 are outlined below.

Based on prior analysis, motivation was indexed dichotomously: a score of less than 20 on the 5-item motivation scale was coded as 0, and a score of 21 or greater was coded as 1. Peer environment was indexed by an aggregate of how many of the following three statements related to science at school applied: "Most of my friends: a) liked science at school; b) did well in science at school; d) hope to become scientists, doctors or engineers". Family structure was coded as 1 if student lived with both parents during the last two years of high-school (i.e., with an intact family), or coded as 0 if the students did not. Parents' educational attainment was indexed by the higher of the mother's or father's completed level of education: primary school or less, high-school, and tertiary education (i.e., a college, technikon, or university qualification). Whether the students' parents had an occupation that was directly related to science, engineering, medicine, or technology was indexed dichotomously: if at least one parent had such an occupation the variable was coded as 1, if neither of the parents had such an occupation it was coded as 0. On the basis of prior analysis, parental encouragement was also indexed dichotomously: affirmative responses to two or fewer statements on the 6-item parental encouragement scale was coded as 0, whereas affirmative responses to three or more statements was coded as 1. Parental involvement was similarly indexed: a score of 0 on the 7-item parental involvement scale was coded as 0, whereas a score of one or more was coded as 1. Academic home resources were indexed individually (i.e., "a specific place to do your homework or to study", "a bedroom of your own", "a daily newspaper", etc.), as well as by an aggregate of how many of the latter six academic home resources together with either the first or the second were available to them.

**Table 7.1.** Description of variables and latent constructs available for modelling predictors of scientific literacy. The reliability ( $\alpha_{20}$ ), mean ( $M$ ), and standard deviation ( $SD$ ) is given for each variable. Asterisks indicate variables that were excluded from the full, initial logistic regression model (see text for details - p. 160).

No.	Variable/Latent construct	Coding	$\alpha_{20}$	$M$	$SD$
1.	Age	Years	-	19.0	0.9
2.	Gender	0 = Female, 1 = Male	-	0.52	0.50
3.	Matric result	6-point scale: A, B, C, D, E, F	-	-	-
4.	Number of science subjects taken in matric	4-point scale: none, 1, 2, or 3	-	1.7	0.8
5.	Science subject combination	7 major combinations: Biology, Biology and Physical Science, Biology and Geography, etc.	-	-	-
6.	Mathematics	Whether taken in addition to science subjects: 0 = no, 1 = yes	-	0.85	0.36
7.	Class size	Number of students per science class: one estimated average for student's science subject combination	-	26.2	8.9
8.	Science club member	0 = no, 1 = yes	-	0.13	0.33
9.	Science-related holiday job	0 = no, 1 = yes	-	0.15	0.35
10.	Instructional objectives	10-item composite: e.g. "Increasing student's awareness of importance of science in daily life"; 4-point scale: 1 = almost never, 4 = very often	0.81	24.9	5.2
*11.	Science class activities	11-item composite: e.g. "Discuss TV programs about science"; 4-point scale: 1 = almost never, 4 = very often	0.81	24.1	5.5
*12.	Open-endedness	7-item composite (SLEI); 5-point scale: 1 = never, 5 = always	0.62	15.6	4.1
13.	Participation	5-item composite (ICEQ); 5-point scale: 1 = never, 5 = always	0.78	19.5	3.8
14.	Personalisation	5-item composite (ICEQ); 5-point scale: 1 = never, 5 = always	0.81	19.2	4.0
15.	Rule clarity	4-item composite (CES); 5-point scale: 1 = never, 5 = always	0.67	13.7	3.3
*16.	Classroom environment	Aggregate of 12-15	0.82	68.1	10.5
*17.	Instructional quality	Aggregate of 10, 11, and 16	0.91	117.2	18.4
18.	Homework for all science subjects	Hours per week	-	4.9	4.1
19.	Interest in science	3-item composite: e.g. "I enjoy science"; 5-point scale: 1 = strongly agree, 5 = strongly disagree	0.77	10.6	2.5
20.	Perceived usefulness of science	4-item composite: e.g. "Science helps a person think logically"; 5-point scale: 1 = strongly agree, 5 = strongly disagree	0.70	14.6	2.9
*21.	Attitude towards science	Aggregate of 19-20	0.80	25.2	4.7
*22.	Persistence	2-item composite: e.g. "I tried hard to do my best at school"; 5-point scale: 1 = never, 5 = always	0.73	8.4	1.6

Table 7.1 continued

No.	Variable/Latent construct	Coding	$\alpha_{20}$	<i>M</i>	<i>SD</i>
*23.	Intrinsic motivation	3-item composite: e.g. "I day-dreamed at school"; 5-point scale: 1 = always, 5 = never	0.72	8.8	2.7
*24.	Motivation	Aggregate of 22-23; 0 = score $\leq$ 20, 1 = score $\geq$ 21	-	0.20	0.40
	<i>Most of my friends:</i>				
*25.	Liked science at school	0 = no, 1 = yes	-	0.41	0.49
*26.	Did well at science in school	0 = no, 1 = yes	-	0.39	0.49
27.	Were really good students in school	0 = no, 1 = yes	-	0.54	0.50
*28.	Hope to become scientists, doctors or engineers	0 = no, 1 = yes	-	0.39	0.49
29.	Go to university, technikon, or college	0 = no, 1 = yes	-	0.86	0.35
30.	Watch a lot of TV	0 = yes, 1 = no	-	0.47	0.50
*31.	Peer environment	Aggregate of 25, 26, and 28; 1 = all three statements apply, 0 = fewer than three apply	-	0.18	0.38
32.	Exposure to TV in general	Number of hours spent watching TV per week	-	9.7	8.1
	Exposure to science-related media:	At least once per month:			
33.	Print media	Read article in science magazine or book, and science-related articles in newspaper or women's magazine; 0 = no, 1 = yes	-	0.79	0.41
34.	Broadcast media: TV	Watched a science-related program on TV; 0 = no, 1 = yes	-	0.80	0.40
35.	Broadcast media: radio	Listened to science-related program on radio; 0 = no, 1 = yes	-	0.21	0.41
36.	Population group	Derived from Examination authority and Home language: African, Coloured, Indian, White	-	-	-
37.	Family size	Number of siblings	-	2.3	1.5
38.	Family structure	Living with intact, two-parent family; 0 = no, 1 = yes	-	0.72	0.45
39.	Parents' highest educational attainment	3-point scale: 1 = "primary school or less", 2 = "high-school", 3 = "university, technikon, or college"	-	2.4	0.7
40.	Science-related occupation of parents	At least one parent has occupation related to science, engineering, medicine, or technology; 0 = no, 1 = yes	-	0.42	0.49
41.	Parental encouragement	6-item composite: e.g. My parents "expected me to do well in science at school", "think that science is a very important subject"; 0 = 2 or fewer apply, 1 = 3 or more apply	-	0.53	0.50

Table 7.1 continued

No.	Variable/Latent construct	Coding	$\alpha_{20}$	<i>M</i>	<i>SD</i>
42.	Parental involvement	7-item composite: six cultural venues visited together with parents (e.g., museum, planetarium, zoo, etc.), and "my parents really enjoy doing things with me"; 0 = score < 1, 1 = score $\geq$ 1	-	0.72	0.45
43.	Specific place to study	0 = no, 1 = yes	-	0.82	0.38
44.	Own bedroom	0 = no, 1 = yes	-	0.82	0.38
45.	Daily newspaper	0 = no, 1 = yes	-	0.66	0.47
*46.	Weekly news magazine (e.g., "Newsweek", etc.)	0 = no, 1 = yes	-	0.43	0.49
*47.	Science magazine (e.g., "National Geographic", "New Scientist", etc.)	0 = no, 1 = yes	-	0.21	0.41
48.	Atlas or globe	0 = no, 1 = yes	-	0.62	0.49
49.	Personal computer	0 = no, 1 = yes	-	0.39	0.49
50.	Pocket calculator	0 = no, 1 = yes	-	0.95	0.22
51.	Academic home resources	Aggregate of 46-51, and 44 or 45	-	4.9	1.7
52.	Number of books available at home	5-point scale: 1 = "fewer than 50", 5 = "more than 500"	-	3.0	1.3

As described in Chapter 5, the nine Black languages spoken in South Africa were used together with the formerly racially-based examination authorities to derive the population group of students. Neither the home language nor the examining authority variable was therefore used, as each one would only mimic the population group variable.

In the following section, the development of a multivariate logistic regression model of predictors of scientific literacy based on the above student sample is described.

## DATA ANALYSIS

Regression methods have become standard tools for describing the relationship between a response variable and one or more explanatory variables. In the case of scientific literacy, students were classified as either scientifically literate or not, and the response variable is thus not continuous but dichotomous. For such binary outcome variables, logistic regression is the appropriate method for regression analysis (Collett, 1991; Hosmer & Lemeshow, 1989). This form of regression has become the standard method of regression analysis for dichotomous data in many fields, especially the health sciences (Hosmer &

Lemeshow, 1989; Schlesselman, 1982) in which the identification of factors associated with a disease is analogous to the analysis performed here.

The ease with which coefficients estimated by logistic regression can be interpreted is the fundamental reason why this regression method has proved to be such a powerful analytic tool (Hosmer & Lemeshow, 1989). The exponentiated estimated coefficient of a variable is the odds ratio and is a measure of association: the odds ratio approximates how much more likely (or unlikely) it is for a particular outcome to be present among individuals with a given attribute than among individuals without this attribute, given that all other variables are held constant (Hosmer & Lemeshow, 1989; Schlesselman, 1982). The odds of an outcome is the ratio of the probability of the outcome occurring in one population or sample to the probability of the outcome not occurring in the same population or sample. The odds ratio, in turn, is simply the ratio of the odds of an outcome occurring in population A to the odds of an outcome occurring in population B, given that population A and B differ in a particular attribute (Schlesselman, 1982). The odds ratio is thus a measure of association between the outcome and the attribute under investigation (Hosmer & Lemeshow, 1989; Schlesselman, 1982). In this study, the outcome is presence of scientific literacy, and the various student background variables are the attributes under investigation.

A further advantage of this regression method is that once the coefficients have been determined, the estimated probability of success for the outcome variable (i.e., the probability of being scientifically literate) is easily calculated by the equation

$$\pi = \frac{e^{\beta_0 + \beta_1 x}}{1 + e^{\beta_0 + \beta_1 x}}$$

where  $\pi$  is the estimated probability of success, and  $\beta$  is the estimated vector of the coefficient of one or more variables included in the logistic regression model (Hosmer & Lemeshow, 1989).<sup>1</sup> The exponentiated expression is the estimated logit, and is referred to later in the results section.

### Construction of the logistic regression model

The purpose of the analysis described below was to seek a parsimonious model of predictors of scientific literacy of South African matriculants entering tertiary education for the first time, that still explains the data. The rationale for minimising the number of variables in a regression model is that the resultant model is more likely to be numerically stable, and thus more easily generalised (Hosmer & Lemeshow, 1989). Model instability may arise because the more variables are included in a model, the greater the estimated standard errors become, and the more dependent the model becomes on the observed data (Hosmer & Lemeshow, 1989). As can be seen from Table 7.1, at least 52 variables and unobservable

1. The potential use of determining the probability of being scientifically literate for individual students for admission and placement tests for entry into tertiary education is elaborated on and discussed in Chapter 8.



compound variables were believed to have a potential association with scientific literacy. The strategies and associated methods recommended by Hosmer and Lemeshow (1989) were therefore used to deal with the selection of statistically and conceptually significant variables, as well as with the model-building process in general. The statistical software packages used in the regression analyses were Statistical Analysis System (SAS, Version 6) and programme LR of BMDP (Release 7).

The variable selection process began with a careful univariate analysis of each variable listed in Table 7.1. For nominal and ordinal variables, this analysis was first performed with a contingency table of outcome ( $y = 0, 1$  where 1 = scientifically literate), in order to obtain a 'feel' for the data. Similarly, the first analysis of continuous variables involved a two-sample  $t$ -test. These analyses were then followed by a univariate logistic regression analysis, with appropriate design or dummy variables for categorical variables. As suggested by Hosmer and Lemeshow (1989), any variable whose univariate test had a  $p$ -value of less than 0.25 was considered as a candidate for the multivariate model.

Forty-seven variables were selected in this manner. This number was still too large for all variables to be included in the model, and the following reasoning was used to narrow down the selection further. If all variables were of no explanatory value, one would expect the  $p$ -value of each of the 47 variables to be distributed randomly between 0 and 1. If, however, one regarded one out of 47 as an acceptable error rate (i.e., one out of the 47 variables might be included in a multivariate model when this variable, in fact, did not have a significant association with scientific literacy), then particularly appropriate variables would be those with a  $p$ -value of less than 0.021 (1:47). Five variables which did not fit this criterion were eliminated in this way. Variables that are aggregates of other variables (e.g., classroom environment, instructional quality, etc.) were also excluded from the initial model, as their constitutive components were already included.

Based on univariate analyses and other considerations described above, 39 variables together with relevant design variables were selected for inclusion in the initial logistic regression model of predictors of scientific literacy. Variables excluded from this model either because of insufficiently small  $p$ -values or because of the compound nature of the variable, are marked with an asterisk in Table 7.1. Although the full 39-variable model was significant ( $L = 602.34$ , d.f. = 59,  $p < 0.0001$ ), only the following eight variables together showed any evidence of having some association with scientific literacy in the full model: gender, matric result, science club membership, interest in science, exposure to print media, population group, presence of an atlas or globe in the home, and the estimated number of books available at home. Given that all 39 variables were shown to exhibit a statistically significant association with scientific literacy in univariate analyses, the fact that only eight variables seemed to be associated with scientific literacy in the multivariate model seemed at first sight surprising and contradictory. Overall matric result is, however, associated with population group ( $\chi^2 = 1136$ , d.f. = 12,  $p < 0.0001$ ) - as is evident from Table 7.2. Given the extent to which the South African educational context is influenced by

issues related to population group (Chapter 6), results of the multivariate model suggested that the full model was being dominated by effects reflected by population group categories. A separate multivariate logistic regression model was therefore carried out for White students, who were numerically the largest group in the sample (Chapter 5). As will be described below, the data in fact suggested only two regression models of predictors of scientific literacy: one for White and Indian students, and another for Coloured and African students.

**Table 7.2.** The distribution of overall matric examination symbols for students of different population groups who participated in this study. Fifty-eight students did not report their matric result.

Matric symbol	African	Coloured	Indian	White	Total
A	3	45	7	499	554
B	23	179	23	687	912
C	97	354	19	733	1203
D	243	402	13	473	1131
E or F	205	95	5	64	369
Total	571	1075	67	2456	4169

Although each of the two models was determined separately, the general principles recommended by Hosmer and Lemeshow (1989) for the construction of logistic regression models were applied to both models. As the univariate analyses were performed on the racially undifferentiated data set, it was not unreasonably assumed that some variables did not exhibit any statistically significant association with scientific literacy because of possible opposite effects due to different population groups. (In the preliminary analyses it was, for example, found that peer environment was such a case.) Hence all 52 variables were considered available for inclusion in the differentiated models. In each case a purposeful selection of the variables listed in Table 7.1 was carried out, and each multivariate model was begun with the consideration of each of the seven variables identified in the initial, full model (excluding population group). The inclusion of each of these variables in the model was checked (see below), and other individual variables were then added to the model in the order of a perceived hierarchy of association to scientific literacy of the various areas addressed by the variables: educational, socio-economic, and demographic. In general, the inclusion of each additional variable in the multivariate model was justified on the basis of each variable's explanatory value, given that other variables had already been included in the model at an earlier stage. The explanatory value of each variable was assessed on the basis of the likelihood ratio test for the difference between the model containing the additional variable, and the model without the new variable (Hosmer & Lemeshow, 1989). The likelihood ratio test statistic,  $G$ , was

compared to a chi-square distribution with one degree of freedom for continuous and dichotomous variables, and to a chi-square distribution with  $k-1$  degrees of freedom for polytomous variables with  $k$  categories (Hosmer & Lemeshow, 1989). A  $p$ -value of 0.05 or less demonstrated that the additional variable contributed at a statistically significant level to the multivariate model of scientific literacy. The importance of each variable included in the model was verified by examining the value of the Wald statistic ( $W$ ), which is the ratio of the estimated coefficient to the estimated standard error of the coefficient (Hosmer & Lemeshow, 1989). This statistic follows the standard normal distribution under the hypothesis that an individual coefficient is zero, and is therefore an indication of whether the variable under inspection is significantly associated with the outcome or not (Hosmer & Lemeshow, 1989). The standard 5% significance level was used. For categorical variables, the Wald statistic and sign of the estimated coefficient of design variables was used to explore more meaningful groupings of categories. This process of fitting new variables, deleting, refitting and verifying continued until the inclusion of all variables was tested for, and until all of the important variables were included in the model and those excluded were either conceptually or statistically unimportant.

In this manner, a multivariate logistic regression model for White students - the most numerous population group in the sample (Chapter 5) - was constructed. Compared with the reference group of White students, the Wald statistic of the Indian category in the initial undifferentiated, full model had indicated that the Indian category was not a statistically significant one in the population group variable ( $W = 0.1513$ ,  $p = 0.70$ ), in contrast to the Wald statistic of the African and Coloured categories. When Indian students were included in the White model, no statistically significant difference in the likelihood ratio test statistic became apparent ( $G = 0.866$ , d.f. = 1,  $p > 0.05$ ), indicating that the White/Indian distinction did not contribute to the model. The coefficient of the variables also did not change appreciably when the Indian students were included in the model, indicating that there was no interaction between the White or Indian variable with other variables in the model. Hence, one logistic regression model was built for both White and Indian students. Similarly, a second model was built only for Coloured students, the second-most numerous population group in the sample (Chapter 5), and when African students were added, no significant difference in the likelihood ratio test statistic became apparent ( $G = 1.970$ , d.f. = 1,  $p > 0.05$ ). Hence, a second logistic regression model was built for Coloured and African students. Each of the two models is now described in greater detail below.

### ***Model 1: White and Indian matriculants***

The final multivariate logistic regression model of predictors of scientific literacy for White and Indian matriculants ( $L = 288.9$ , d.f. = 8,  $p < 0.0001$ ) is based on the analysis of the responses of 1086 scientifically illiterate and 1117 scientifically literate students ( $n = 2203$ ). The following five statistically

and conceptually important variables were included in this model: science subject combination, science club membership, interest in science, and the presence of an atlas or globe and a personal computer in the home (Table 7.3). None of the other variables listed in Table 7.1 contributed significantly to the logistic regression model of predictors of scientific literacy for White and Indian matriculants after the above five variables were included.

In Table 7.3, for each of the variables listed in the first column, the following information is presented: (a) the estimated slope coefficient ( $\beta$ ); (b) the estimated standard error of the estimated slope coefficient ( $SE(\beta)$ ); (c) the estimated odds ratio, which is obtained by exponentiating the estimated coefficient; and, (d) the 95% confidence interval for the odds ratio. At the 5% significance level, the endpoints for this interval are given by the expression (Hosmer & Lemeshow, 1989)

$$\exp [\beta \pm 1.96 \times SE(\beta)].$$

As mentioned earlier, the odds ratio is an important measure of association in logistic regression analysis (Hosmer & Lemeshow, 1989; Schlesselman, 1982), and hence both point and interval estimates are given here for this parameter.

**Table 7.3.** The estimated coefficient ( $\beta$ ), estimated standard error ( $SE(\beta)$ ), estimated odds ratio, and the 95% confidence interval (CI) for the odds ratio for each variable contained in the logistic regression model of predictors of scientific literacy for White and Indian matriculants. The relevant description of design variables is given in parentheses.

Variable	$\beta$	$SE(\beta)$	Odds ratio	95% CI
SSC (B)	-0.865	0.148	0.42	0.31, 0.56
SSC (B & G)	-0.684	0.184	0.50	0.35, 0.72
SSC (PS)	-0.282	0.112	0.75	0.61, 0.94
SSC (B & G & PS)	0.707	0.168	2.03	1.46, 2.82
SCI CLUB	0.355	0.136	1.43	1.09, 1.86
INTEREST	0.201	0.021	1.22	1.17, 1.27
ATLSGLB	0.316	0.107	1.37	1.11, 1.69
PC	0.296	0.095	1.34	1.12, 1.62

The combination of science subjects taken in matric by White and Indian students was initially analysed with reference to the most common science subjects inferred from Table 7.4, namely Biology and Physical Science. (Direct data on the number of matriculants taking different science subject combinations are in fact not readily available in South Africa [personal communication, Mr C. Shepard, Human Sciences Research Council, January 1996].) Further analysis revealed that although the combination of Geography and Physical Science contributed significantly to the model ( $G = 55.8$ ,

d.f. = 1,  $p < 0.001$ ), the 95% confidence interval of the estimated odds ratio of this combination included 1. This result indicated that there was no significant difference between this combination and the reference group (Hosmer & Lemeshow, 1989), and both subject combinations, that is Biology and Physical Science, and Geography and Physical Science, therefore formed the final reference group.

Variables with negative estimated coefficients are negatively associated with scientific literacy. The causal sequence is assumed to proceed from science subject combination to scientific literacy, and results show that students taking Biology, Biology and Geography, and Physical Science, are respectively only 42%, 50%, and 75% as likely to be scientifically literate as students taking Biology and Physical Science, or Geography and Physical Science (Table 7.3). On the other hand, students taking all three science subjects, namely Biology, Geography and Physical Science, are about twice as likely to be scientifically literate compared with students in the reference group (Table 7.3).

**Table 7.4.** The number of African, Coloured, Indian, and White students sitting for the matric examination in 1993 in five widely taken natural science subjects as the percentage of the total number of candidates (EduSource, 1994b; unpublished data). Row percentages do not add up to 100% because students could take more than one science subject. Physiology was not offered for African students in Transkei, nor for Coloured and White students.

	Total number of candidates	Biology <sup>a</sup> (%)	Physical Science <sup>a</sup> (%)	Geography (%)	Agricultural Science (%)	Physiology (%)
African	366 241	87	15	45	28	0.4
Coloured	25 735	85	22	45	0.3	N/A
Indian	15 203	68	40	-	-	-
White	63 769	51	44	34 <sup>b</sup>	4 <sup>b</sup>	N/A

Note. Data for subjects other than Biology and Physical Science were not available for Indian students.

<sup>a</sup> EduSource (1994b)

<sup>b</sup> A low estimate, since the percentage is based on the number of students who *passed*. Data on the number of candidates who sat for the exam were unavailable.

Individuals who were members of a science club or society at school were 43% more likely to be scientifically literate than students who did not belong to such a club or society. For every one-point increase in the score of students on the 15-point interest-in-science scale, the odds that students were scientifically literate increased by 22% (Table 7.3). Out of a suite of seven home resources considered to be potentially associated with scientific literacy, only an atlas or a globe, and a personal computer made significant contributions to the regression model for White and Indian students. For students in whose home each of these resources was present, the odds of being scientifically literate increased by 37% and 34%, respectively (Table 7.3).

According to the regression model, the estimated logit ( $g$ ) for White and Indian students is given by the equation

$$g = -2.50 + a \times \text{SSC} + 0.355 \times \text{SCI\_CLUB} + 0.201 \times \text{INTEREST} \\ + 0.316 \times \text{ATLSGLB} + 0.296 \times \text{PC}$$

where  $a$  represents the coefficient of the applicable science subject combination of the suite of possible ones given in Table 7.3. The coefficient of the reference group combinations (i.e., Biology and Physical Science, and Geography and Physical Science) is zero.

### ***Model 2: Coloured and African matriculants***

The final multivariate logistic regression model of predictors of scientific literacy for Coloured and African matriculants ( $L = 174.1$ , d.f. = 10,  $p < 0.0001$ ) is based on the analysis of the responses of 953 scientifically illiterate and 323 scientifically literate students ( $n = 1276$ ). The following six statistically and conceptually important variables were included in this model: matric result, science subject combination, interest in science, motivation, the number of resources available in the home, and family structure (Table 7.5). None of the other variables listed in Table 7.1 contributed significantly to the logistic regression model of predictors of scientific literacy for Coloured and African students after the above six variables were included.

**Table 7.5.** The estimated coefficient ( $\beta$ ), estimated standard error ( $SE(\beta)$ ), estimated odds ratio, and the 95% confidence interval (CI) for the odds ratio for each variable contained in the logistic regression model of predictors of scientific literacy for Coloured and African matriculants. The relevant description of design variables is given in parentheses.

Variable	$\beta$	$SE(\beta)$	Odds ratio	95% CI
MATRIC (A)	1.857	0.360	6.40	3.16, 13.00
MATRIC (B)	1.241	0.192	3.46	2.37, 5.04
MATRIC (C)	0.763	0.160	2.15	1.57, 2.94
SSC (B & G & PS)	0.751	0.202	2.12	1.43, 3.15
SSC (B & PS)	0.912	0.185	2.49	1.73, 3.58
SSC (PS)	1.130	0.408	3.09	1.39, 6.88
INTEREST	0.103	0.037	1.11	1.03, 1.19
MOTIVATN	-0.393	0.155	0.67	0.50, 0.91
NO_HRES	0.179	0.053	1.20	1.08, 1.33
FS	0.330	0.163	1.39	1.01, 1.91

The addition of matric result made a very significant contribution to the regression model of scientific literacy of Coloured and African students ( $G = 107.04$ , d.f. = 4,  $p < 0.001$ ). The largest proportion of

these students obtained a 'D' as their overall matric result (Table 7.2), and this mark was therefore used initially as the reference group for the variable matric result. Further analysis revealed that although a matric result of 'E or F' contributed significantly to the model ( $G = 71.7$ , d.f. = 1,  $p < 0.001$ ), the 95% confidence interval of the estimated odds ratio of 'E or F' included 1. This result indicated that there was no significant difference between this result and a 'D', and matric results of 'D', 'E', or 'F' therefore formed the final reference group for this variable. Compared with students who had obtained a 'D, E, or F', students who had achieved a 'C', 'B', or 'A' as their overall matric result were more than two, three, and six times as likely to be scientifically literate, respectively (Table 7.5).

In contrast to White and Indian students, the most widely taken science subject amongst Coloured and African students is Biology (Table 7.4). Biology was hence used initially as the reference group for the various combinations of science subjects. Further analysis revealed that although the combination of Biology and Geography contributed significantly to the model ( $G = 58.6$ , d.f. = 1,  $p < 0.001$ ), the 95% confidence interval of the estimated odds ratio of Biology and Geography included 1. This result indicated that there was no significant difference between this combination and Biology, and both Biology alone and Biology together with Geography therefore formed the final reference group. Students taking any of the three subject combinations listed in Table 7.5 were about two to three times more likely to be scientifically literate compared with those who had only taken Biology, or Biology and Geography. Students taking only Physical Science had the highest odds of being scientifically literate (Table 7.5).

Just as in the case of White and Indian students, interest in science was also an important variable in the logistic regression model for Coloured and African students. For every one-point increase in the score of students on the 15-point interest-in-science scale, the odds that students were scientifically literate increased by 11% (Table 7.5). Motivation was negatively associated with scientific literacy (Table 7.5), and a scale of motivation coded in quartiles made a statistically and conceptually more significant contribution to the model than a continuously coded scale ( $G = 8.63$ , d.f. = 3,  $p < 0.05$ ). The 95% confidence interval of the estimated odds ratio of the second and third quartiles, however, contained 1, indicating that these quartiles were not significantly different from the first one, the reference group. Although a binary coding of motivation (i.e., first three quartiles [score  $\leq 20$ ] versus the fourth quartile [score  $\geq 21$ ]) did not contribute to the model statistically ( $G = 1.00$ , d.f. = 1,  $p > 0.25$ ), this coding was retained because of its conceptual contribution to the model of predictors of scientific literacy. Coloured and African students who achieved a score of 21 or higher on the 25-point motivation scale were only 67% as likely to be scientifically literate as those students who scored lower (Table 7.5).

In contrast to the model for White and Indian students, the total number of home resources, rather than specific ones, contributed significantly to the model for Coloured and African students. For every additional resource available in their home, students were 20% more likely to be scientifically literate than those who did not have these resources available to them (Table 7.5). The odds of being literate for

students coming from an intact, two-parent family is 39% higher compared with students who live with relatives or come from single-parent families (Table 7.5).

According to the regression model, the estimated logit ( $g$ ) for Coloured and African students is given by the equation

$$g = -4.15 + a \times \text{MATRIC} + b \times \text{SSC} + 0.103 \times \text{INTEREST} \\ - 0.393 \times \text{MOTIVATN} + 0.179 \times \text{NO\_HRES} + 0.330 \times \text{FS}$$

where  $a$  and  $b$  represent the coefficient of the applicable overall matric result and science subject combination of the suite of possible ones given in Table 7.5, respectively. The coefficient of the reference group for matric result (i.e., D, E, or F) and science subject combination (i.e., Biology and Biology and Geography) is zero.

### Assessment of goodness-of-fit

Once a logistic regression model has been constructed, it is important to assess how effective the model is in describing the outcome variable. When the model is 'correct', that is when all the conceptually and statistically important variables have been included in the model and when the variables have been entered in the correct functional form, one hopes to find that the model will fit the data well. An answer to the question of whether the predicted values are an accurate representation of the observed values is what assessments of goodness-of-fit provide. There are essentially two approaches to assessments of goodness-of-fit (Hosmer & Lemeshow, 1989). The first provides a global or summary measure of the goodness-of-fit of any postulated mathematical model to the observed data. Observed data, however, consists of various covariate patterns (i.e., different combinations of values of the variables used in the regression equation) together with the observed probability for each pattern - in this case the probability of being scientifically literate. Because the data exhibit this covariate pattern structure, careful methodology demands that one also examines the goodness-of-fit for individual patterns, that is, whether fit is supported over the entire set of covariate patterns. This second approach to assessing goodness-of-fit involves a series of specialised measures falling under the general heading of regression diagnostics, which are used to identify those covariate patterns which (a) are likely to be influential on the final choice of parameters in the model, (b) are actually influential in the data set of interest (i.e., large numbers of cases share a pattern), and (c) are associated with a large residual or difference between the fitted and observed probabilities. The identification of influential covariate patterns is, however, a very detailed process (Hosmer & Lemeshow, 1989) which is beyond the scope of the current study, and hence only a summary measure together with a visual appraisal of goodness-of-fit is presented here for each model.

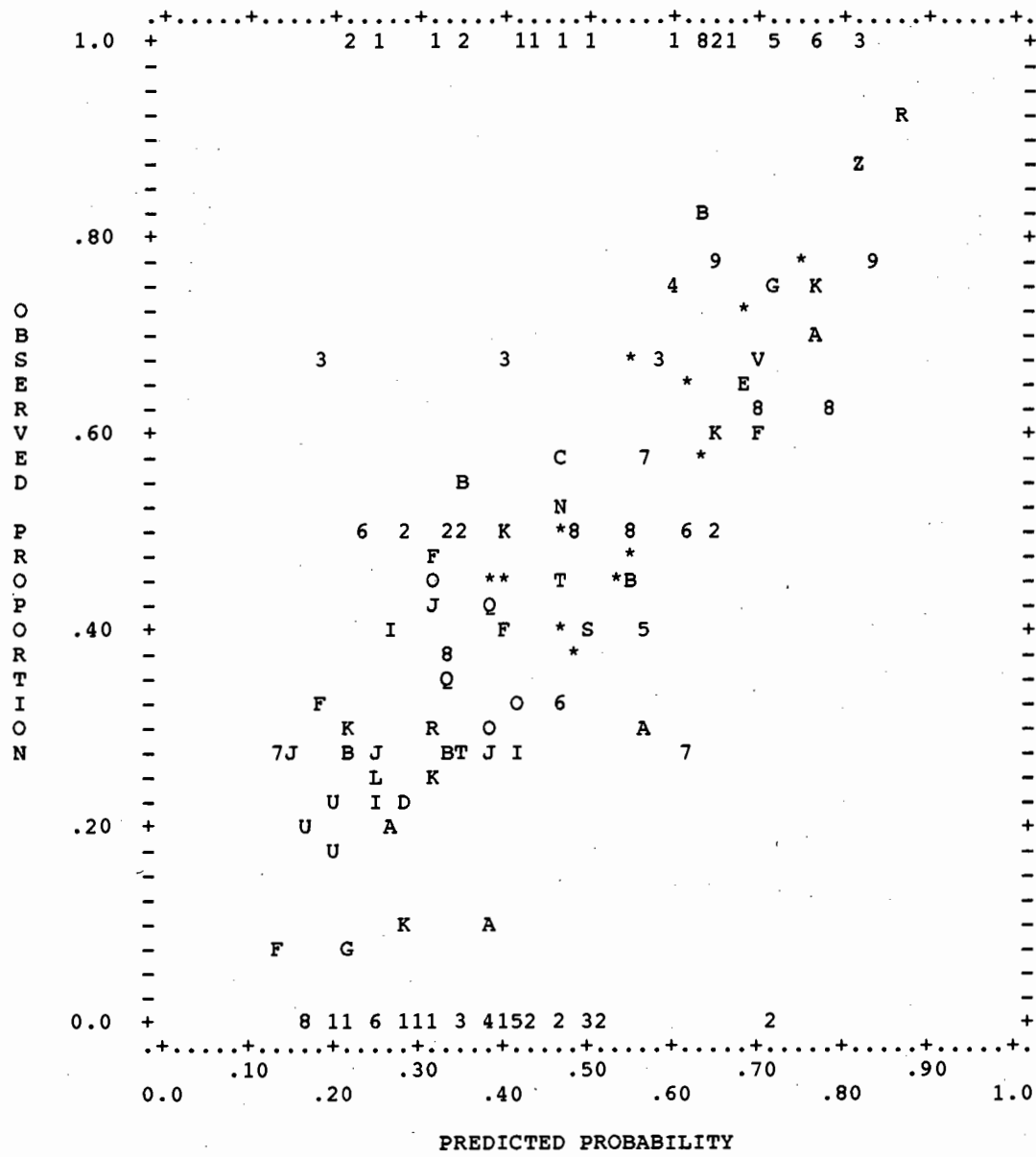
A summary statistic that provides a single, easily interpretable, value is the Hosmer-Lemeshow statistic  $C$ . This statistic provides an assessment of goodness-of-fit based on the sum of residuals for each



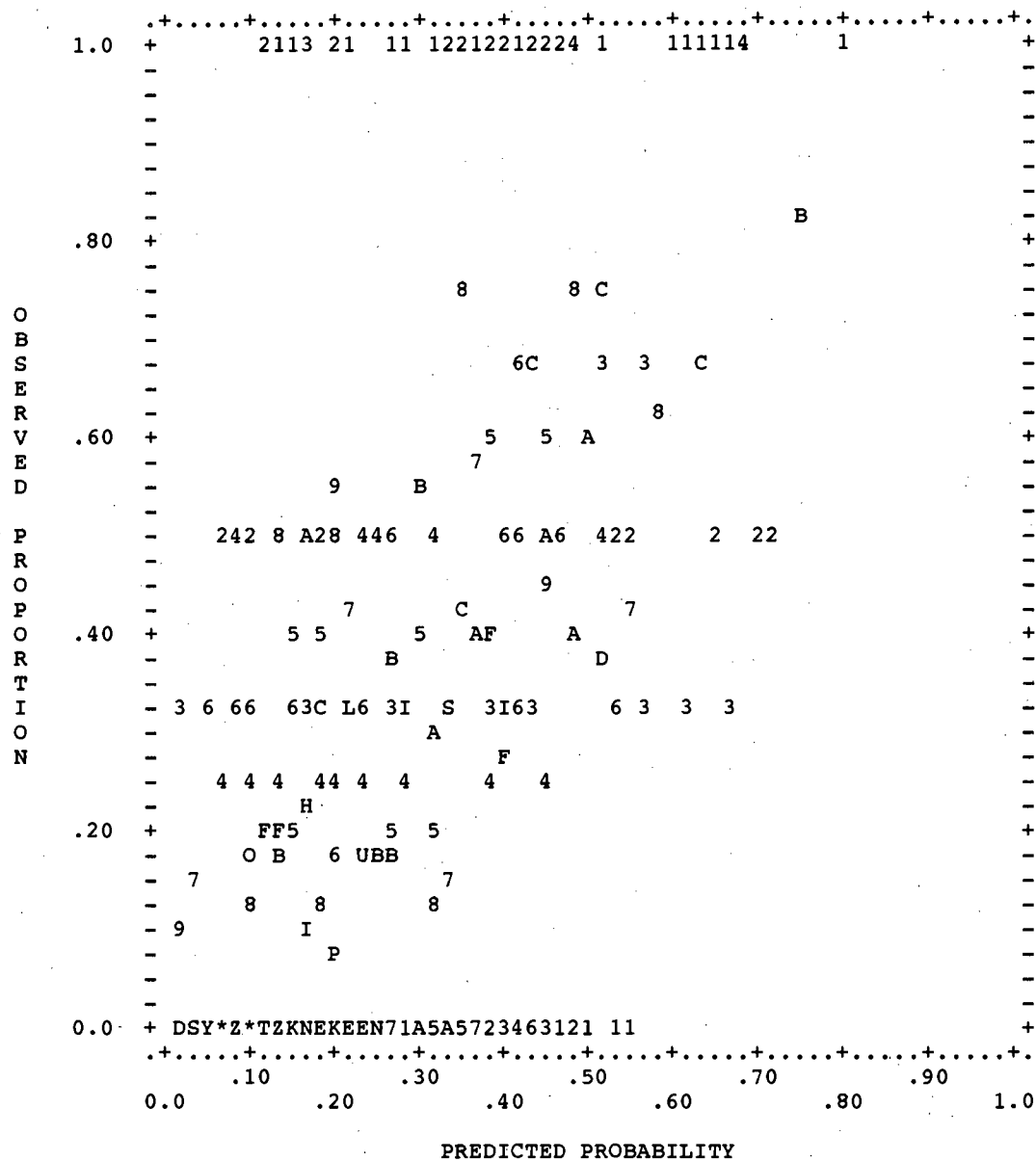
decile of risk (i.e., for each of 10 percentiles of the estimated probabilities computed from the regression model) over the population of each outcome of the response variable (i.e., scientific literacy and scientific illiteracy) (Hosmer & Lemeshow, 1989). The distribution of the statistic  $C$  is well approximated by the chi-square distribution with 8 degrees of freedom (Hosmer & Lemeshow, 1989), and a large goodness-of-fit chi-square, or a small  $p$ -value, indicates that the fit may be poor (Afifi & Clark, 1990; Dixon, 1992). A large number of distinct covariate patterns occur when continuous variables are used thus reducing the number of individuals per covariate pattern for a constant sample size (Afifi & Clark, 1990). As the  $C$  statistic is based on  $m$ -asymptotics, that is, on the assumption that the number of individuals per covariate pattern becomes large (Hosmer & Lemeshow, 1989), the continuous variables in each model were coded categorically using quartiles. In the first model, this change of coding was performed for the interest variable and reduced the number of covariate patterns from 304 to 139. In the second model, a categorical coding of the interest and number of academic home resources variables was used, and reduced the number of covariate patterns from 751 to 398. The calculated value of the  $C$  statistic for the logistic regression model for White and Indian, and Coloured and African, students was 5.15 ( $p = 0.74$ ) and 3.65 ( $p = 0.89$ ), respectively. These sets of values indicate that both models seem to fit the data well.

A visual assessment of how well the observed values fit the predicted values is provided by a scatterplot of the observed proportion of 'successful' individuals versus the predicted probability of success per covariate pattern. In such a plot, points should fall along a straight line extending from the lower left to the upper right to indicate perfect fit. Such an empirical probability plot for the logistic regression model for White and Indian students shows that covariate patterns fall along a 45 degree line for virtually the entire range of predicted probabilities, and that few patterns contain only one individual (Figure 7.2). This indicates that this model provides predicted probabilities of success (i.e., of being scientifically literate) that generally fit the observed proportions of scientifically literate individuals very well. Two regions of observed proportions exist where this is not the case, namely in regions where the observed proportions are equal to zero and one, suggesting that for individuals in these covariate patterns the variables included in the model do not predict a student's scientific literacy adequately. Fortunately, few individuals exhibit such ill-fitting covariate patterns, so that the model is unlikely to be seriously affected by them.

Covariate patterns of the logistic regression model for Coloured and African students also fall along a 45 degree line, but do not conform for the entire range of predicted probabilities and are more scattered around the line (particularly above it) than in the first regression model (Figure 7.3). Nevertheless, not all covariate patterns in the greater scatter are of equal importance as there are many groups with a small number of individuals. These features of the distribution of covariate patterns indicates, firstly, that the



**Figure 7.2.** An empirical probability plot of the observed proportion versus the predicted probability for all covariate patterns of the logistic regression model for White and Indian students. The plotted numbers represent the number of individuals per pattern (A = 10, B = 11, etc.). An asterisk indicates that the number of individuals per covariate pattern exceeds 35.



**Figure 7.3.** An empirical probability plot of the observed proportion versus the predicted probability for all covariate patterns of the logistic regression model for Coloured and African students. The plotted numbers represent the number of individuals per pattern (A = 10, B = 11, etc.). An asterisk indicates that the number of individuals per covariate pattern exceeds 35.

model for Coloured and African students fits the data adequately but that the fit is not as good as that for White and Indian students, and secondly, that predicted probabilities of being scientifically literate appear to be estimated somewhat conservatively for Coloured and African students. As in the first model, there are again two regions where the predicted probability of being scientifically literate does not match the observed proportion of being scientifically literate (Figure 7.3). In contrast to the first model, the number of Coloured and African individuals in ill-fitting covariate patterns is small only for patterns where the observed proportion is equal to 1 (the model is thus unlikely to be affected by this group), but not where the observed proportion is equal to zero (Figure 7.3). This indicates that although the second model appears to function adequately in predicting scientific literacy, it appears to be less successful in predicting scientific illiteracy. Fine-tuning the present model for Coloured and African students by, for example, replicating the logistic regression model using an appreciably larger sample of African students, would therefore seem to be an important area for further research, as it is this group of students that constitutes the majority, and a rapidly increasing proportion, of matriculants.

## DISCUSSION

As far as can be ascertained, no attempt has been made to date to investigate the influence of student background variables on the scientific literacy of high-school leavers, either in South Africa or anywhere else. Findings obtained from this study therefore represent a novel contribution to the international debate on scientific literacy. The results of the logistic regression analyses performed here suggest two different models of predictors of scientific literacy in the current period of immediate post-apartheid South Africa - one for White and Indian students, and a second one for Coloured and African students. The logistic regression model built for each of the two groups of matriculants entering tertiary education in the Western Cape represents not *the* but *a* model from a set of possible ones, as the explanatory value of each new variable in the model was assessed with respect to the variables already included earlier in the model. Given the purposeful selection of variables based on conceptual justifications, I am nevertheless confident that the models constructed here have a high degree of coherent explanation in terms of the measured variables in this context. This is further confirmed by the assessment of goodness-of-fit presented above.

The two logistic regression models are now interpreted and discussed, and the general implications of the findings are examined.

### Model 1: White and Indian matriculants

The combination of science subjects taken in high-school was an important predictor of scientific literacy in the model for White and Indian matriculants. The odds ratios permit a ranking of the various science subject combinations with respect to the subject's relative influence on scientific literacy (Table 7.6). The fact that some science subjects and subject combinations were excluded from the model because of lack of statistical significance makes an absolute comparison of the influence of particular science subjects on scientific literacy not possible. Nevertheless, two issues emerge from the relative ranking. Firstly, there does not appear to be any difference in the influence of either Biology or Geography on the scientific literacy of matriculants when each subject is combined with Physical Science. This lack of difference suggests that the original effect of Biology and Geography on scientific literacy may be similar. This conclusion seems to be supported by the minor increase in the odds ratio of Biology and Geography compared with Biology (Table 7.6). Secondly, Physical Science was included in each of the three most important science subject combinations (Table 7.6), indicating the important role that this subject appears to play in the scientific literacy of matriculants.

**Table 7.6.** A relative ranking of science subject combinations with respect to their influence on scientific literacy for White and Indian matriculants. The size of the influence is given by the odds ratio relative to the reference group.

Influence on scientific literacy	Science subject combination	Odds ratio
+	Biology, Geography and Physical Science	2.03
0 (ref. group)	Biology and Physical Science, Geography and Physical Science	1
-	Physical Science	0.75
-	Biology and Geography	0.50
-	Biology	0.42

The relative ranking of the various science subject combinations with respect to the subjects' different effect on scientific literacy confirm the ranking of science subject combinations based on levels of scientific literacy of White students (Chapter 6, Table 6.9, p. 125). However, in contrast to the analyses of Chapter 6, analyses performed here control for other variables included in the logistic regression model, and rankings presented in Table 7.6 therefore give a more accurate picture of the effects of science subject choice on scientific literacy. For example, in comparison to White matriculants taking

Biology and Physical Science or Geography and Physical Science, White matriculants taking Biology together with Geography and Physical Science appear to be far more scientifically literate than a simple comparison of levels of scientific literacy suggests (cf. Chapter 6, Table 6.9, p. 125).

Science club membership made a significant difference to the odds of being scientifically literate, and it is likely that club membership exerts its influence on scientific literacy in a similar manner to attitude toward science. Science club activities frequently extend the scope of experimentation routinely carried out at school, and very often also include topics that promote an awareness of science-related and environmental issues. In general, therefore, it is likely that students participating in science clubs and science societies at school have an enriched perspective of science and of its relationship to society. However, the absence of a clear and demonstrable cause and effect sequence between science club membership and scientific literacy also makes it possible that students take part in after-school science activities precisely because they are scientifically literate.

Students who displayed a strong agreement with "I enjoy science", "I am good at science", and "I usually understood what we did in science at school" were also more likely to be scientifically literate than students who displayed a weak agreement with these statements (Table 7.3). It is reasonable to assume a link between perceived interest in science and scientific literacy, particularly as attitude to science has been found to be an important factor in contributing to science achievement (Schibeci & Riley, 1986). Interest, together with perceived usefulness of science, formed the attitude to science scale (Table 7.1), but it was the contribution of interest alone that was significant to the model of predictors of scientific literacy (Table 7.3). This finding suggests that, in contrast to having an interest in science, it may be more difficult for matriculants to have a positive view of the usefulness of science, particularly in respect of how science can be useful in their own life. Science teachers who regularly provide opportunities to address or to discuss the usefulness of science in their classes may therefore contribute to the formation of a more positive attitude toward science on the part of their students, and may thus increase their students' scientific literacy or predispose them to achieving scientific literacy.

It is notable that for White and Indian students it is not the overall number of academic home resources that is significantly associated with scientific literacy but rather specific resources such as an atlas or a globe, and a personal computer (Table 7.3). It appears likely that the use of an atlas or globe has a positive effect on scientific literacy through increased awareness of the context of the earth in the universe, as well as through increased knowledge of geographical and environmental issues often addressed by such resources. In the case of the personal computer, however, I believe that the presence of this academic resource in the home is much more likely to reflect an elevated occupational status of the parents (see, for example, Reynolds & Lee, 1991). A higher occupational status, in turn, may be an indicator of an increased likelihood of the existence of a more nurturing social home environment in comparison to homes where no personal computer is available, where the occupational status of parents

is thus lower, and where the educationally supportive home environment may therefore be less pronounced. Nevertheless, the possibility that the use of a personal computer at home may positively influence scientific literacy directly is not dismissed.

Predictors of scientific literacy for White and Indian matriculants were thus largely characterised by science subject combination, a comparatively well developed interest in science, and academic home resources that in my opinion do not necessarily represent a direct association with scientific literacy but rather point towards a generally supportive and educationally conducive home environment.

### **Model 2: Coloured and African matriculants**

High overall matric results of scientifically literate students suggest that students were successful not only in science but also in other subjects, indicating that students were well-rounded, knowledgeable, and motivated in other spheres in addition to that of science. The uneven distribution of matric results with respect to population group (Table 7.2) is, however, a reflection of the effects of the differential education policy under apartheid (see, for example, Hartshorne, 1992; Chapter 6). In order to obtain a high matric symbol, African high-school students need to be not only able but exceptionally hardworking and committed to school work, since they frequently also have to overcome the handicap of underqualified teachers and large classes in schools with limited or extremely poor facilities (Hartshorne, 1992; Kahn & Rollnick, 1993; Kallaway, 1984b; Chapter 6). The same argument also holds for Coloured students, although their schooling conditions are frequently of a somewhat better standard (Chapter 6). The negative association of motivation with scientific literacy for Coloured and African students would therefore seem at first to be counter-intuitive (even in the case of univariate logistic regression motivation was negatively associated with scientific literacy for this group of students), as motivation has been shown to be positively associated with science achievement (Kremer & Walberg, 1981; Reynolds & Walberg, 1991, 1992; Tamir, 1989). The following argument suggests a reason for the observed relationship.

The literature on student learning shows that study behaviour is influenced by a number of factors that include differing forms of academic motivation (Biggs, 1985; Entwistle & Ramsden, 1983; Entwistle & Kozéki, 1985), qualitative differences in students' perceptions of and approaches to learning, and features of academic disciplines differing between, for example, the sciences, social sciences, and arts (e.g., forms of assessment, vocational relevance, etc.) (Entwistle & Ramsden, 1983). Different forms of motivation (i.e., intrinsic, extrinsic, and achieving) are thought to be associated with characteristically different ways of studying (Biggs, 1985; Entwistle & Kozéki, 1985), the most basic distinction being between the deep and surface approaches to learning (Marton & Säljö, 1984, Entwistle & Ramsden,

1983). By surface approach is meant a sterile engagement with subject content, in which the learner invests minimal time and effort consistent with appearing to meet assessment requirements (Biggs, 1994). (An example of this approach is the strategy of rote learning of selected content without understanding.) By deep approach is meant an engagement with subject content that attempts to maximise understanding in various ways (Biggs, 1994; Entwistle & Ramsden, 1983). In South Africa, research on the retrospective study behaviour of mostly African first-year Engineering students at three universities revealed that some students appear to have adopted a surface approach to their study of Physical Science at school (Cliff, 1992, 1995; Meyer, Dunne, & Sass, 1992). Although the following argument does not take into consideration differing forms of motivation, it can be postulated that students who display a surface approach to learning do not inevitably increase their understanding of science concepts by being highly motivated, because they do not employ the necessary strategies to establish personal meaning for the required subject content but may be simply performing more of the same inappropriate study behaviour such as, for example, rote learning. In the present survey, for example, over 91% of the 600 African and Coloured students who were located in the top quartile of scores on the motivation scale indicated that they always worked harder if they obtained bad marks at school. If South African students apply a surface approach not only to their study of Physical Science but also to that of other natural science subjects (e.g., Biology and Geography) - and in the absence of any data there is no justification to believe this concurrence to be an unreasonable assumption - then it is possible that scientific literacy is negatively associated with motivation. Higher levels of motivation may well be accompanied by approaches to learning that do not lead to an increased understanding of important science concepts related to scientific literacy. This finding is unusual and provides a direction for further research.

**Table 7.7.** A relative ranking of science subject combinations with respect to their influence on scientific literacy for Coloured and African matriculants. The size of the influence is given by the odds ratio relative to the reference group.

Influence on scientific literacy	Science subject combination	Odds ratio
+	Physical Science	3.09
+	Biology and Physical Science	2.49
+	Biology, Geography and Physical Science	2.12
0 (ref. group)	Biology, Biology and Geography	1

Just as in the model for White and Indian students, the combination of science subjects taken in high-school was an important predictor of scientific literacy in the logistic regression model for Coloured and



African matriculants. The relative ranking of science subject combinations reveals two findings. Firstly, the influence of Physical Science on scientific literacy is again highlighted, as this subject is included in the three most influential science subject combinations (Table 7.7). The important role that Physical Science appears to play in predicting scientific literacy for Coloured and African students in particular is indicated by the fact that the odds of being scientifically literate become appreciably higher when this subject is combined with Biology or Biology and Geography - the reference group in this comparison - or when Physical Science is taken on its own (Table 7.7). This finding is explicable in terms of the suggested reasons advanced in Chapter 6 to account for the superior performance on each subtest of the TBSL of students who took Physical Science in comparison to students who took Biology.

Secondly, the lack of statistical significance between the inclusion of Biology and that of Geography in the model again suggests that there does not appear to be any difference in the influence of either subject on the scientific literacy of Coloured and African matriculants. This conclusion corroborates the findings based on the model for White and Indian students, as well as those obtained in Chapter 6. Conflicting evidence, however, may be provided by the fact that Coloured and African students who took Biology, Physical Science, and Geography were slightly less likely to be scientifically literate than students who took only the first two subjects (Table 7.7). This result is counter-intuitive and one can speculate that Black students who took all three subjects despite generally poor school facilities were possibly 'stretched too thin' in order for this subject choice to have the anticipated significant, positive effect on the students' scientific literacy.

Large numbers of Black matriculants not only come from poor quality school environments, but often also from lower socio-economic strata. The inclusion of the number of academic home resources in the model of predictors of scientific literacy, together with the absence of any other indicators of home environment that are strongly and statistically significantly associated with scientific literacy, suggests that these resources are an indicator of home environment (see, for example, Reynolds & Lee, 1991), rather than being directly related to scientific literacy. The latter explanation is, however, not dismissed. The higher the number of different academic resources available in the home, the higher the likelihood of a home having the stable, constructive, and educationally supportive environment that is reasonable to assume is necessary for the growth of scientific literacy.

This view is supported by the inclusion of family structure in the regression model (Table 7.5), which shows that Coloured and African students coming from intact, two-parent homes had appreciably higher odds of being scientifically literate than students who did not come from such families. As family configuration was included here in a multivariate analysis in which the effects of different variables on scientific literacy were examined while all other variables included in the model were held constant, the latter result is notable for two reasons. Firstly, it suggests that in contrast to general student achievement (e.g., Kurdek & Sinclair, 1988; Marsh, 1990), the effect of family structure on the scientific literacy of

matriculants is likely to be substantial even when other family background variables and school variables have been controlled. Secondly, the result does not appear to support the conclusion of Jubber (1994) and Marsh (1990) that family configuration had little effect on school performance in the last two years of high-school (Chapter 6). In the light of the above findings, a more focused examination of the role of family structure in the scientific literacy of matriculants would thus appear to be a potentially important avenue for further research.

Predictors of scientific literacy for Coloured and African students were thus characterised by indicators of general success at school, moderate levels of motivation, science subject combination, an interest in science, as well as a supportive and educationally conducive home environment.

## General

Variables common to the logistic regression model of predictors of scientific literacy of Indian and White, and Coloured and African, students were science subject combination, interest in science, and home atmosphere as indicated by academic home resources. The consistent significance of science subject combination is explicable in terms of the importance of science content knowledge in scientific literacy. The association between science knowledge and scientific literacy is, however, to be expected to some extent, as the items of the Science Content Knowledge Subtest of the TBSL represent a substantial proportion of the scientific literacy test-items (Chapter 4, Table 4.2, p. 70).

Findings from a multivariate analysis of the effect of different variables on scientific literacy - as measured by the TBSL - suggest that Biology and Geography do not have a significantly different influence on the scientific literacy of South African matriculants. This lack of difference corroborates previous findings obtained from a univariate analysis of important variables related to scientific literacy, and suggests that students taking either science subject are likely to have acquired similar competencies with respect to scientific literacy (Chapter 6). Although the relationship between Physical Science and scientific literacy - and hence its use as a predictor of scientific literacy - was more marked for Coloured and African students than for White and Indian students, Physical Science was shown to play an important role in predicting the scientific literacy of both groups of matriculants. In the light of the hypothesised explanations accounting for the superior performance of students who took Physical Science on all three subtests of the TBSL (Chapter 6), this result is not unexpected. Implications of the relative ranking of science subject in this study are that Physical Science may be recommended for students of all population groups wishing to take only one science subject, whereas either Biology or Geography should be chosen additionally by students wishing to take two science subjects in matric.

It would appear to be intuitively reasonable to postulate that interest in science is somehow associated with scientific literacy, and this study has confirmed that this variable is indeed an important predictor of

this concept. However, what is less clear is the direction of the sequence of causation between these two variables. Does scientific literacy lead to an interest in science, or does an interest in science precede scientific literacy? Both sequences are clearly possible. However, given the comparatively sophisticated nature of the concept - it involves not only substantive knowledge in science but also an understanding of the nature of science and an awareness of the interaction between science, technology and society - it is probable that an initial interest in science may well provide the spark that lights the fire (proverbially speaking). Only thereafter would it seem plausible for the relationship between interest in science and progress towards scientific literacy to proceed in the form of a positive feedback loop (i.e., in a mutually beneficial manner).

Moreover, the findings of this study on the importance of interest in science as a predictor of scientific literacy are also consistent with those reported by other investigators with respect to science achievement, even though interest in science formed only part of the attitude toward science scale here. For example, Keeves (1975), Pifer (1995), Schibeci (1989), and Schibeci and Riley (1986) presented evidence of a causal link from attitude towards achievement, and Tamir (1989) reported high correlations between interest and science achievement. Considering that cause-effect relationships between student background variables and scientific literacy have yet to be established (but cannot be identified through logistic regression modelling), it would seem to be reasonable to hypothesise the same causality from attitude toward scientific literacy as for science achievement. The implication of these findings for science teachers is that teachers cannot afford to overlook student attitudes: not only *what* teachers teach, but also *how* they teach, can make a difference to the scientific literacy of their students.

This study has identified both the overall number as well as the presence of particular home resources as having important influences on the scientific literacy of matriculants. These results are notable for two reasons. Firstly, they are consistent with findings from a LSAY-based study, in which home science resources were found to have the greatest total effects on ninth grade science achievement (Pifer, 1995). Secondly, the results obtained here suggest - in the absence of any other direct indicator of home environment - that what happens in the home has an influence on the scientific literacy of students. This conclusion is of course not new, as measures of material resources at home have been found to form an important part of the home environment (Reynolds & Lee, 1991), and home environments are known to influence student achievement in science (e.g., Kremer & Walberg, 1981). The implication of this conclusion, however, is that if a stable, educationally supportive home environment is indeed an important factor in fostering scientific literacy, then it would appear that the social upliftment of many South Africans may well be both a consequence of, and a prerequisite for, scientific literacy. It is of course realised that general upliftment (i.e., increased wealth) does not automatically translate into educationally more supportive home environments but rather provides a potential for such improvements.

Both logistic regression models of predictors of scientific literacy were not only notable in terms of the student background variables that were shown to be associated with scientific literacy but also in terms of the variables that were excluded from the regression models, that is, variables that were shown to have relatively less important associations with scientific literacy in the presence of the chosen variables. Simple variables and unobservable compound variables in this second group include gender, classroom environment (i.e., instructional objectives, science class activities, open-endedness of laboratory sessions, etc.), the influence of parents (i.e., parental encouragement and involvement), and the educational level and occupation of parents. The absence of gender in both models of predictors of scientific literacy is in contrast to the widely documented association between gender and science achievement (see, for example, references cited in Kelly [1981, 1987a, 1987b]). However, given the importance of science subject combination in both models, particularly that of Physical Science, and given the fact that in comparison to female students a significantly higher proportion of male students took Physical Science in matric (Chapter 6), it appears probable that the effect of science subject combination subsumed any effect of gender on scientific literacy. Similarly, the absence of any variables related to classroom environment in both models of predictors of scientific literacy suggests, given the inclusion of other variables in the model at an earlier stage, that an indicator of the direct influence of science teachers on the development of scientific literacy of students is also subsumed by science subject combination and interest in science. The extent of the influence of parents' characteristics on their children's level of scientific literacy is not as yet well understood, and it is very likely that parental influences on scientific literacy may well manifest themselves only in more complex interactions that cannot be adequately observed and investigated with the self-reported retrospective data used in this study.

In general, therefore, the results of this exploratory study indicate that the relative effect of major school variables (i.e., science subject combination and overall matric result) on scientific literacy was more pronounced than that of home environment variables (as measured here, e.g., parental encouragement and involvement, education level of parents, etc.). Moreover, the present results point towards the importance of variables that are 'alterable' (Staver & Walberg, 1986), such as, for example, science subjects and interest in science, and that can therefore be influenced by educators. The findings of this study thus present directed challenges for devising strategies of intervention that have as their ultimate goal the widespread scientific literacy of matriculants in South Africa.

## CONCLUSION

The purpose of this chapter was to determine the predictors of scientific literacy for South African matriculants, and to establish whether predictors are similar for all students. In this manner it was intended to ascertain which student background variables appear to have the most influence on whether matriculants are scientifically literate or not. For both White and Indian, and Coloured and African students, adequate logistic regression models were constructed which cannot be simplified by deletion of variables except at the expense of worse-fitting estimates of regression coefficients. The logistic regression models revealed that although all groups of South African matriculants share a set of student background variables that are associated with scientific literacy, additional variables such as overall matric result and motivation were found to be associated only with the scientific literacy of Coloured and African students. This study confirmed intuitive relationships between certain major student background variables and scientific literacy, but also highlighted the unexpected role of motivation in scientific literacy. In general, the group of variables identified here is consistent with variables shown by other studies to be important factors associated also with general science achievement.

The findings of this study have resulted in the identification of a number of pertinent and meaningful directions for further research. Moreover, in order to enhance the general understanding of the relationships between scientific literacy and variables related to student, school, and home, it is necessary that further studies are undertaken that identify which other factors are associated with scientific literacy, the strength of any relationships, and the direction of any hypothesised line of causality. The inter-related nature of the factors also requires an examination of scientific literacy within a context that allows the determination of the *relative* influence of each of several factors associated with scientific literacy - a task that is problematic using logistic regression methods (Schlesselman, 1982).

This exploratory study has provided models of predictors of scientific literacy applicable to a profile of a cross-section of the current population of matriculants entering tertiary education in the Western Cape. These models are unlikely to be permanent, as the profiles of students are likely to change due to intervention, changed socio-economic priorities, social upliftment, and improved education provision. As the profiles of White, Indian, Coloured, and African students draw closer to each other and start to converge, new models highlighting the importance of different student background variables to achieving scientific literacy will undoubtedly need to be developed. It was particularly fortunate that this study was carried out at the beginning of 1994, just before the first democratic elections were about to take place in South Africa, as this therefore represents a unique baseline study of the scientific literacy of a sizeable group of matriculants entering tertiary educational institutions in this country.





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## Chapter Eight

### SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter aims to summarise the main stages in the development of the scientific literacy test instrument, as well as the main findings of the thesis. In addition, it seeks to mould the various chapters into a cohesive unit.<sup>1</sup>

This study was conducted against the background of immediate post-apartheid South Africa in which the social upliftment and improvement of living conditions of all South Africans is regarded as a high priority. Such development can realistically only be achieved by vigorous, sustained, and export-led economic growth, in which science and technology are widely acknowledged to play an important role. The development of the required human resources is seen to be crucial not only in influencing the supply of such human resources, but also in the realisation of a democracy in which "... responsible and productive citizens will be enabled to participate fully in all facets of the life of their communities and the nation at large" (ANC, 1994b, p. 3). In addition, future South Africans will need to be able to make informed decisions with regard to the various environmental challenges likely to face them as a result of the large-scale development required for the social upliftment of all South Africans.

All of the above issues, that is the development of human resources in the fields of science and engineering, and the generation of effective and socially productive citizens, are widely recognised to be related to the concept of scientific literacy. Individuals successfully completing 12 years of school (i.e., matriculants) represent the country's future labour force and general public, and must be regarded as the final product of the education system. It was therefore deemed appropriate to examine the ability of the science education provided by the recent South African education system to generate scientifically literate matriculants. The findings of such an investigation will hopefully provide useful information for future (science) education policy in South Africa.

The purpose of this study was (a) to determine the level of scientific literacy of matriculants entering tertiary education for the first time; (b) to describe patterns of scientific literacy levels with respect to selected demographic and other student background variables; and (c) to ascertain which student background variables appear to have the most influence on determining whether matriculants are scientifically literate or not. Students entering the five major tertiary educational institutions in the Western Cape (i.e., the Cape and Peninsula Technikons and the Universities of Cape Town, Stellenbosch

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1. Statements are not referenced in this chapter if they are substantiated elsewhere in the thesis.



and the Western Cape) comprise a substantial proportion of South Africa's full-time residential student populations. Moreover, these five institutions comprise a broad range of different faculties, and consist of three historically White (i.e., the Cape Technikon, and the Universities of Cape Town and Stellenbosch) and two historically Black (i.e., the Peninsula Technikon and the University of the Western Cape) institutions, thus representing a suitably diverse student population. Students at these institutions were thus chosen as suitable for investigating the above research questions.

## CONSTRUCTION OF A SCIENTIFIC LITERACY TEST INSTRUMENT

Underpinning the above research aims was the development of an inexpensive, reliable, and valid scientific literacy test instrument. A pool of scientific literacy test-items was developed first, and the scientific literacy test based on these items was constructed subsequently.

With only two exceptions, recent composite measurements of scientific literacy are all based on the work of Miller and his colleagues. Miller proposed a 'three-constitutive dimensions' model of scientific literacy, defining scientific literacy as consisting of an understanding of the norms and methods of science (i.e., the nature of science); of key scientific terms and concepts; and an awareness and understanding of the impact of science and technology on society. Despite being widely accepted, items based on Miller's research methodology are, however, unsuited to inexpensive and swift administration to large numbers of respondents. Hence an alternative but essentially complementary approach to measuring scientific literacy was used.

### Development of the scientific literacy test-item pool

A major challenge in any development of a test instrument of scientific literacy is the identification of appropriate content from which to generate test-items. Measures of scientific literacy should ideally be based on items testing comprehension and awareness of important principles in, and attitudes toward, science on which there is widespread, documented agreement that these principles and attitudes form part of what it means to be scientifically literate. The 1989 AAAS overview report on literacy goals in science, mathematics and technology, entitled *Science for all Americans*, is - to the best of my knowledge - the only publication that represents a consensus view of the knowledge, skills, and attitudes all high-school leavers should possess as a consequence of their total school experience in order to be regarded as scientifically literate. Moreover, the major reason advanced by *Science for all Americans* for promoting scientific literacy amongst American high-school leavers is in accordance with the primary argument given for promoting widespread scientific literacy in South Africa, namely human resource development

to satisfy national socio-economic needs. The content of *Science for all Americans* was thus deemed appropriate also for the South African context, and it was on selected chapters of this publication that the development of a scientific literacy test-item pool, and hence the construction of the *Test of Basic Scientific Literacy*, was based.

The AAAS recommendations consist of 12 chapters of varying length, addressing different knowledge, skills and attitudes in a variety of different domains. In the present study, five chapters were selected to be used in the construction of item pools for the three dimensions of scientific literacy in accordance with Miller's multi-dimensional model. Selected sentences containing key ideas in, and attitudes toward, science were validated by a substantial number of Fellows of the Royal Society of South Africa, and these sentences formed the stems from which the scientific literacy test-items were developed. The general purpose of the items was to achieve broad coverage of Miller's three dimensions of scientific literacy, as levels of scientific literacy had yet to be investigated in a large-scale, systematic manner in South Africa. In order to achieve the desired content coverage in the inevitably limited time available for testing, a true-false item format was chosen. Great care was taken in the transformation of item stems into matched true-false test-items. Various widely accepted guidelines for writing effective true-false items were adhered to, and it was attempted in a variety of ways to ensure that each item was meaningful to the respondent. The language demand of the test-items appropriate for English second language speakers also received careful attention, and the item-writing procedure as a whole was designed to minimise possible unintentional ambiguities in the test-items.

The validity of the items was evaluated in various different ways. The items are based on AAAS recommendations contained in *Science for all Americans* and therefore possess a significant degree of content validity. The test-item pool is, however, based only on selected chapters of *Science for all Americans* and is therefore not grounded in the complete 'content universe' of the *Science for all Americans* model of scientific literacy. A substantial degree of construct validity was evident from the fact that almost 60% of all test-items were covered as explicit benchmark statements in *Benchmarks for science literacy*. These benchmarks were developed during Phase II of *Project 2061* and contain the key ideas in science that students in particular grade spans need to understand on their way to becoming scientifically literate. Item validity was evaluated by a panel of judges and involved both item-objective congruence and the technical quality of the items.

The criterion-referenced nature of the test-items makes it possible to investigate individuals' comprehension of particular concepts in science as the items were developed with respect to an agreed to, and clearly defined, domain of content. In the South African context, where matric results are not always regarded as a reliable indicator of academic ability, this feature of the test-items is potentially useful for alternative or supplementary admission and placement procedures for students wishing to commence studies in science and engineering at universities and technikons. An investigation of the usefulness of the

test-items for the above purposes represents an important and highly relevant direction for further research.

The distinguishing feature of the pool of 472 test-items of scientific literacy generated in this study is, however, that the individual items test for comprehension of concepts and for possession of appropriate attitudes toward science that according to the AAAS need to be acquired in order to be regarded as scientifically literate. The test-items thus test *whether* individuals possess the required knowledge and skills recommended by the AAAS, but do not probe *why* individuals hold particular positions (which may or may not be contrary to the recommended ones). The scientific literacy test-item pool is unequivocally based on a consensus view of the American scientific community of what it means to be scientifically literate, located within the context of Miller's 'three constitutive dimensions' definition of the concept. The 'content universe' of scientific literacy has been further distilled by a substantial number of Fellows of the Royal Society of South Africa, the country's premier professional science society. There now exists a more clearly circumscribed content pool of important ideas in, and attitudes toward, science that further delimits the knowledge and attitudes required by the AAAS recommendations in order to be regarded as scientifically literate. As test instruments ideally need to be validated for particular target groups and uses, selecting appropriate (e.g., discriminating) items for different target groups can be cumbersome because of the often inadequate number of test-items to choose from. Using either the refined content pool or the pool of scientific literacy test-items (or both), researchers will now be able to, and will find it more convenient, to develop multiple, reliable, valid, and rigorous measures of scientific literacy (or measures of any of its dimensions) that are targeted at specific groups of interest to the researcher. The refined content pool as well as the pool of scientific literacy test-items are therefore a significant and useful resource in developing valid measures of scientific literacy in a wide variety of different contexts - both in South Africa and elsewhere.

Due to the format of the test-items and the approach used in developing the items, the scientific literacy test-items address some of the previously identified shortcomings of Miller's research methodology for financially limited, large-scale surveys of scientific literacy. The test-items developed in this study not only possess a substantial degree of content validity, but can also be rapidly administered in a comparatively inexpensive manner to a large number of respondents, as the research methodology does not rely on telephone or face-to-face interviews. Scoring the structured-response scientific literacy test-items is also less complex than open-ended or free-response items (see, for example, Miller, 1993), so that the preparation of the data for analysis is likely to be more rapid. In general, therefore, the development of the scientific literacy test-item pool represents a different, but essentially complementary, approach to measuring scientific literacy to that used by Miller and his colleagues, and expands the data-gathering options available to researchers in conducting surveys of scientific literacy.

Limitations of the pool of test-items are essentially related to the fact that the majority of items attempt to assess only the extent, quality, and structure of the information base the AAAS recommends all high-school leavers should possess in order to be regarded as scientifically literate, and not *all* aspects of scientific literacy recommended in *Science for all Americans*. The construction of test-items for the remaining aspects of scientific literacy (i.e., knowledge of interdisciplinary concepts as well as applications of science, and the ability to apply knowledge for decision-making and problem-solving) therefore provide directions for further research. Qualitative investigations of the functioning of the test-items employing, for example, small case studies or interviews to examine the cognitive processes underlying item responses, would clearly be a further useful avenue of research.

### **Construction of the *Test of Basic Scientific Literacy* (TBSL)**

The principal purpose of the TBSL is to identify minimally scientifically literate high-school leavers and the test has been constructed and validated for those South African matriculants entering universities and technikons for the first time. In order to identify suitable test-items that can be used to distinguish between scientifically literate and scientifically illiterate matriculants, an evaluation of both the true and false version of all items was conducted by means of a pilot test. Using an uninstructed-instructed approach, all test-item versions were administered in four pilot test-forms to 625 first-year students in the sciences and humanities at one university, technikon and college of education in Cape Town. Item difficulty and item discrimination indices appropriate for criterion-referenced test-items were obtained from this pilot administration of the test-items. Student feedback received during the pilot test, the above two indices, and the importance rankings provided by Fellows of the Royal Society of South Africa in the validation of key concepts in, and attitudes toward, science, formed the basis on which the final selection of test-items for the TBSL was made. The final form of the TBSL consists of 110 items; 22, 72 and 16 test-items for the Nature of Science Subtest, the Science Content Knowledge Subtest, and the Impact of Science and Technology on Society Subtest, respectively. Each subtest corresponds to one of Miller's constitutive dimensions of scientific literacy.

Examination of the content, item, and construct validity of the test-items included in the TBSL revealed that the test-items are indeed valid. The TBSL is constructed from items that were based on key ideas in, and attitudes toward, science contained in *Science for all Americans* - a document that, as has been shown, possesses a substantial degree of content validity. Although not representing every aspect of scientific literacy contained in *Science for all Americans* but nevertheless covering each of Miller's constitutive dimensions of scientific literacy, the test-items used in the TBSL sample the domain of possible test-items in equal proportion to the content areas of the test-item pool. Moreover, in a large proportion of the TBSL test-items, the content was corroborated by benchmark statements which were arrived at independently of this study.

In order to be able to distinguish between the competent and incompetent (i.e., the scientifically literate and illiterate), a performance standard for each of the three subtests was established. Employing an Angoff procedure, 258 members of seven key South African professional science and engineering associations assigned to each test-item in their area of expertise a probability which represents the estimated likelihood that minimally scientifically literate South African matriculants will answer the item correctly. The resulting performance standards mean that in order to be regarded as minimally scientifically literate, matriculants would have to obtain scores of at least 13 out of 22, 45 out of 72, and 10 out of 16, on each of the above subtests of the TBSL, respectively.

Employing a contrasting groups approach using the top-100 competitors of the South African National Youth Science Week (the 'known' competent group) and first-year students in a local college of education (the 'known' incompetent group), the competence classifications were found to correspond to hypothesised classifications for both groups of White and Black students. These results provided evidence that the performance standard decided on the basis of expert opinion is in fact likely to be valid. Moreover, estimates of the internal consistency of all subtests were found to be above 0.70, with the reliability of the 110-item TBSL calculated to be 0.95. The index of consistency of mastery-nonmastery classification decisions for the overall TBSL ( $p_o = 0.84$ ) was found to be acceptable for criterion-referenced tests used to monitor performance on a day-to-day basis.

The TBSL is unique in that in comparison to other currently available composite measures of scientific literacy it is unmatched in the degree of confidence that the test-items used in such instruments correspond to the major content areas of the theoretical concept the tests are designed to measure. The test breaks new ground in the South African context in particular, as it is the first test instrument of scientific literacy to be constructed and validated for use in this country. Moreover, there is substantial evidence that the TBSL is a valid and reliable instrument for classifying South African matriculants into categories of minimal scientific literacy and scientific illiteracy. The test can be directed at a number of different target groups consisting of individuals who are likely to have started tertiary education (e.g., students, teachers, scientists, consumers, decision-makers, etc.). The TBSL can also be used to describe patterns of scientific literacy, as well as to test hypotheses and to formulate new ones. It is therefore anticipated that the *Test of Basic Scientific Literacy* constructed in this study will open numerous important research avenues that are of relevance to the national and international discourse on scientific literacy.

Limitations of the TBSL are essentially identical to those discussed earlier in relation to the pool of scientific literacy test-items, and are therefore not repeated here. It seems, nevertheless, important to point out again that the test instrument was not designed to test complex cognitive abilities and tests only fundamental, but nevertheless important, aspects of scientific literacy. A number of further directions for research suggest themselves which may include the following. Firstly, it would be important to

investigate potential gender and population group differences with respect to responses to the "Don't know" option, and to explore the effect of this option on the scientifically literate classification of borderline cases. Secondly, it would be useful to carry out additional investigations of the functioning of the test-items (e.g., with respect to the language demands of the items and to the extent of understanding of science concepts the scientific literacy test-items assess). Thirdly, it would be important to investigate the existence of possible unintentional effects of the TBSL such as, for example, whether the test discriminates against individuals from a particular gender, language, or population group. Fourthly, it would be important to gather further evidence of the validity of the performance standards from a variety of criterion groups from educational contexts different to the ones utilised in this study. Fifthly, it would be relevant to the general discourse on scientific literacy to establish to what extent individual and composite measures of the three constitutive dimensions of scientific literacy developed in this study correspond to other measures of this concept (e.g., Miller's research framework). In summary, directions for further research are related to accumulating additional evidence with respect to the validity of the *Test of Basic Scientific Literacy* and its use (cf., Shepard, 1993).

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The above two sections were concerned with the development and construction of assessment tools for scientific literacy. The sections below discuss the application of the test-instrument to matriculants at the secondary/tertiary education interface in the Western Cape, and the most important features of the scientific literacy survey conducted amongst this highly selective group of students is described next.

## SCIENTIFIC LITERACY SURVEY

While the second section of the scientific literacy survey questionnaire consisted of the TBSL, the first section sought to obtain self-reported retrospective data on a number of different student background variables. These socio-demographic variables were largely - but not exclusively - based on and coded similarly to appropriate ones used in the 1987 Longitudinal Study of American Youth. Overall, 53 variables and latent constructs were available for investigating the scientific literacy of matriculants at the secondary/tertiary education interface in the Western Cape. These variables included demographic ones (age, gender, etc.) and indices related to students' school environment (science subjects, matric result, class size, perceived instructional objectives, science class activities, etc.), home environment (highest educational attainment of parents, parental encouragement and involvement, academic home resources, etc.), peer environment, attitude toward science, motivation, and exposure to the mass media. The reliability of these indices were at or close to 0.80, the value recommended for widely used scales.

At the beginning of the 1994 academic year, the scientific literacy survey questionnaire was administered to students registered in a total of 31 carefully selected first-year courses in disciplines broadly divided into areas of specialisation related to engineering, the natural sciences, commerce and management, and the human sciences. At each institution, the selection of courses was based on 1993 student data and on the advice of deans and experienced student advisors. Overall, the questionnaire was administered to 6801 students. However, due to administrative and logistical problems beyond my control, some intended target populations at the two historically Black institutions were inadequately sampled. Once the data had been checked, verified, and cleaned, and the data of students who did not fit the required profile (i.e., those who were older than 23 years of age and/or had matriculated earlier than in 1992) had been eliminated, the final sample consisted of 4227 first-time entering students.

This sample comprised a substantial proportion - about 28% - of all first-time entering students registered at the five tertiary educational institutions during the 1994 academic year. The final sample was slightly skewed in favour of students registered in the natural sciences and engineering, and consisted of a proportionately higher number of White students than encountered in the target population. African students were particularly undersampled due to the sampling difficulties experienced at the historically Black institutions, and the sample size of Indian students was very small. In a social sciences context such as the exploratory study conducted here, where random selection of subjects is limited because of access, cost, and time constraints, it is extraordinarily difficult for the student sample to accurately reflect actual proportions in the target population with regard to even fundamental variables. Given the comparatively large sample sizes (in an absolute sense) used in this survey, important insights into the scientific literacy of African, Coloured, Indian, and White first-time entering students can be obtained despite the limitations of the sample. This is particularly true in the context of this study because a large-scale survey of the scientific literacy of South African students at the secondary/tertiary education interface has not been previously undertaken. The limited sample size (in a relative sense) of African, and particularly Indian, students nevertheless provides directions for further scientific literacy surveys of South African matriculants.

## SCIENTIFIC LITERACY OF SOUTH AFRICAN MATRICULANTS

Essentially two questions provided the motivation for describing and analysing the levels of scientific literacy of students entering the five major educational tertiary institutions in the Western Cape. Firstly, how are patterns of scientific literacy manifested with respect to a number of variables related to the students' background, as well as to the students' school and home environment? Secondly, which

variables appear to have the most influence on the students' level of scientific literacy? The findings and conclusions of this study with respect to the above two concerns are summarised below.

### **Levels of scientific literacy**

Based on the sample of first-time entering students tested in this study, the level of scientific literacy of students from different population groups was found to vary greatly and a clear hierarchy was evident with respect to all variables examined. White and Indian students were most scientifically literate, followed by Coloured and thereafter by African students. The level of scientific literacy of Indian students exceeded that of White students. However, due to the very small sample size of Indian students, this pattern needs to be interpreted with great caution and may, in fact, be spurious. Overall, male students displayed statistically significantly higher levels of scientific literacy than female students, although statistically significant gender-based differences were only observed for African and White students. The scientific literacy level of university students was found to be statistically significantly higher than that of technikon students. In general, students registered for degrees or diplomas in Engineering had the highest level of scientific literacy, followed by students in the Natural Sciences. Next were students in Commerce and Management, while students in the Human Sciences had the lowest level of scientific literacy. Although these rankings varied slightly between students of different population groups, there was a statistically significant difference between the level of scientific literacy of students in the sciences and non-sciences for all population groups.

In general, levels of scientific literacy decreased with increasing age of students, with 18- and 19-year-old students displaying the highest level. Although the sequence of causality between age and scientific literacy is unknown, it is speculated that older students - who in all probability will have repeated one or more years - are generally academically weaker and hence also less scientifically literate. Scientific literacy levels of African students in the 16- to 23-year-old age-range were, however, not statistically significantly different.

The overall scientific literacy levels with respect to major school-related variables such as, for example, matric result and the number of science subjects taken in matric followed an anticipated pattern: the better the matric result and the higher the number of science subjects taken in matric, the higher the level of scientific literacy displayed by students. However, there was a statistically significant difference between the scientific literacy level of students taking two or three science subjects only for Whites. Different science subjects, and different combinations of them, influenced the level of scientific literacy of students from all population groups. Results showed that although the actual scientific literacy level of students taking the same subject varied across population groups, students taking only Biology consistently displayed the lowest level within all population groups. Furthermore, the effect of taking Geography appeared to be similar, and not additive, to Biology, suggesting that there seems to be no



advantage to taking Geography in addition to Biology in terms of increasing the students' level of scientific literacy. The particular role of Physical Science in scientific literacy was highlighted by the fact that the level of scientific literacy of students who included this subject in their science subject combination was consistently higher than that of students who did not.

Three major findings were examined in further detail: the relative influence of Physical Science, Biology and Geography on scientific literacy; the high level of scientific literacy of engineering students; and the hierarchy of scientific literacy levels displayed by students from different population groups. Turning first to the importance of Physical Science, it was shown that students taking only Physical Science possessed a better understanding and awareness of all three dimensions of scientific literacy - based on TBSL subtest scores - than students taking only Biology. It was argued that this superior performance of students taking Physical Science may be related to (a) the greater number of topics placed in an historical context in the South African Physical Science syllabus in comparison to Biology; (b) the greater obvious connection between technology and syllabus topics covered in Physical Science than in Biology; and (c) the comparative ease with which some understanding of concepts in the biological and health sciences may be obtained through informal and non-formal education in comparison with concepts in the physical and chemical sciences. In addition, it was argued that the hypothesised sequence of causality from subject choice to scientific literacy may well be preceded by factors related to an individual's personality and psychological disposition. Furthermore, it was suggested that the lack of difference in the effect of Biology and Geography on scientific literacy was related to similar limitations of the two syllabuses with respect to the first and second dimension of scientific literacy. Moreover, as some of the concepts in the Science Content Knowledge Subtest are related to the environment, it is likely that there is only a limited possible differential effect of Geography and Biology on the scientific literacy of matriculants.

Engineering students were found to have a statistically significantly higher proportion of parents with a science-related occupation than other students. A statistically significantly greater proportion of Engineering students than other students reported a score of four or more on the six-point parental encouragement scale, indicating that such parents are more likely to exert a 'science push'. It was hypothesised that such parents additionally increase the chance that their children are more exposed to science in the broadest sense through informal conversations and family activities, as well as through their professional activities, thus potentially fostering a positive attitude and interest in science on the part of their children. In fact, a statistically significantly higher proportion of Engineering than other students held a holiday job related to science, engineering, medicine, or technology. In general, therefore, the higher level of scientific literacy of Engineering students compared with other students is likely to be attributable to the greater exposure to, and involvement in, a culture of science.

Possible explanations for the hierarchy of scientific literacy levels displayed by students of different population groups were sought among the school and home environment. Using data largely from the annual South African Institute of Race Relations survey, it was shown that the quality of schooling provided for and experienced by students of different population groups during the late 1980s and early 1990s in South Africa varied widely due to discriminatory apartheid policies and the prevailing political climate at the time. The profound differences in the quality of the general school and learning environment experienced by pupils of different population groups were thought to affect the schooling of pupils in more fundamental ways than elements of their specific school environment (e.g., instructional objectives). The 'pecking order' of the hierarchy of inequality was almost always White, Indian, Coloured, and African for whatever recognised education criterion used. It was therefore postulated that the scientific literacy level of students from different population groups reflected the hierarchy in the historical provision of South African education. Particularly disturbing was the high proportion of un- and underqualified African science teachers, which was especially severe in the case of Physical Science and General Science - the latter being the science foundation course for the senior secondary phase.

The home environment is widely recognised as an important factor influencing educational outcomes in general and science achievement in particular. On the basis of self-reported data from the survey, the level of educational attainment was found to be highest for White and lowest for African parents, and academic home resources provided for students by Black parents were substantially fewer than in White homes. The provision of behavioural and psychological resources appeared to be particularly high for Indian students, suggesting a possible reason for the high level of scientific literacy displayed by these students. In general, the educational conduciveness of homes for students of different population groups also tended to reflect the pecking order in the hierarchy of deprivation present in South Africa. The differences in the level of scientific literacy displayed by students of different population groups are therefore likely to be a consequence of both differential school and differential home environments experienced by African, Coloured, Indian, and White students.

Based on the sample of students tested in this study, just over one third of matriculants entering universities and technikons in the Western Cape can - on the basis of the TBSL - be regarded as scientifically literate. This level, and the overall level of scientific literacy of students from different population groups, is essentially not comparable with surveys from other countries as the test-instrument used here is novel, and has not been used elsewhere. Overall levels of scientific literacy must, therefore, be essentially regarded at this stage as observations, until directly comparable data are available. Until levels of scientific literacy amongst *all* high-school leavers, and not only amongst those entering tertiary education, are estimated, it is not possible to make a conclusive appraisal of the ability of the recent South African education system as a whole to produce scientifically literate high-school leavers. A survey of the scientific literacy of a sample of all high-school pupils completing year 12 must therefore be regarded as a very high research priority. Given a number of assumptions, it was nevertheless possible

to carefully extrapolate the scientific literacy data from the Western Cape sample in order to obtain various estimates of the level of scientific literacy of all matriculants. (Indian students were excluded from this extrapolation because of their low sample size.) Based on these estimates, it is speculated that the science education provided by the South African education system to White students may be regarded as acceptable, whereas that provided to African and Coloured matriculants does not reach minimally acceptable levels.

The implications of the above conclusions are that through scientific literacy very few Black South African matriculants (a) will become empowered with respect to public policy decision-making processes, (b) will have the necessary skills and knowledge to cope effectively with science-based issues affecting their lives, and (c) will be motivated to study science, engineering, and technology at tertiary level. Particularly the latter implication is cause for great concern, given the urgent need for a much larger labour force skilled in these areas in order to achieve the necessary economic progress required for social upliftment in South Africa. In attempting to identify steps that could be taken in order to achieve more widespread scientific literacy of matriculants, it is important to identify those factors that appear to have the most influence on whether students are scientifically literate or not. The identification of predictors of scientific literacy facilitated this process.

### **Predictors of scientific literacy**

Current predictors of the scientific literacy of the group of Western Cape matriculants sampled in this study were determined by means of logistic regression. This form of regression has become the standard method of analysis for dichotomous data in many fields, especially the health sciences in which the identification of factors associated with a disease is analogous to the analysis performed here.

The results of the regression analyses suggest two different models of predictors of scientific literacy in the current period of immediate post-apartheid South Africa - one for White and Indian students, and a second one for Coloured and African students. For both models adequate logistic regression models were constructed which cannot be simplified by deletion of variables except at the expense of worse-fitting estimates of regression coefficients. It is, however, important to note that as the explanatory value of each additional variable in the two models was assessed with respect to the variables already included earlier in each model, the model for each group of students represents *a* and not *the* model from a set of possible ones. Nevertheless, the models are believed to have a high degree of coherent explanation in terms of the measured variables, as is demonstrated, for example, by the goodness-of-fit assessment. The model for White and Indian students was, however, slightly better-fitting than that for Coloured and African students, and obtaining a larger sample of African students must be regarded as an crucial step in fine-tuning the latter model.

The logistic regression models revealed that all groups of South African matriculants - based on the present student sample - share a set of student background variables that are associated with scientific literacy, namely science subject combination, interest in science, and academic home resources that were believed to point towards a generally supportive and educationally conducive home environment. Science club membership was found to be associated only with the scientific literacy of White and Indian students, whereas overall matric result and motivation were found to be associated only with the scientific literacy of Coloured and African students.

The importance of overall matric result in the regression model of the latter group of students was interpreted to indicate the dedication and commitment to school work of these students. However, the existence of an unexpected inverse relationship between motivation and scientific literacy for Coloured and African students suggested that students who are likely to employ a less meaningful approach to learning (e.g., a surface as opposed to a deep approach) will not inevitably increase their likelihood of becoming scientifically literate simply as a result of increased motivation. In the light of the above finding, science teachers need to be made aware of the need to design teaching and learning activities that maximise pupils' meaningful engagement with the subject content.

The logistic regression analyses confirmed patterns of scientific literacy with respect to science subject combination described earlier, namely that Physical Science (i.e., physics and chemistry) had an important effect on the scientific literacy of matriculants, and that the effect of Biology and Geography on scientific literacy was similar and not additive. In contrast to the earlier univariate analysis of patterns of scientific literacy levels, the multivariate context of the logistic regression analysis allowed an accurate comparison of the differential effects of these subjects. Results showed that taking Physical Science in addition to, for example, Biology, at least doubled the likelihood that such students would be scientifically literate in comparison to those students who did not take Physical Science. The implications of these findings are that in order to achieve widespread scientific literacy amongst students from all population groups, Physical Science and not Biology should be the science subject of first choice.

The above results and the arguments provided earlier for the possible reason for the particular importance of Physical Science in scientific literacy suggest a number of hypotheses that provide direction for further research. Of particular interest would be to establish whether the importance of physics and chemistry is also related to a fundamental aspect of scientific literacy in other educational and international contexts. In addition, further work is required to establish whether the relative importance of different science subjects in scientific literacy as found in this study is possibly a consequence of the selection of test-items used in the present test instrument. The research framework of experimental studies rather than that of surveys will be more appropriate to this end, and studies using other measures of scientific literacy (and of its constituent dimensions) are very likely to generate further insights.

It is intuitively reasonable to postulate that scientific literacy is somehow associated with interest in science, and this study has confirmed that this variable is indeed an important predictor of this concept. However, what is less clear is the direction of the sequence of causation between these two variables. A causal link in either direction is clearly possible, but the conclusion that interest in science precedes scientific literacy would seem to be a more parsimonious conjecture in the case of comparatively inexperienced matriculants who are likely to have a more tenuous grasp of the sophisticated concept of scientific literacy. Interest in, together with perceived usefulness of, science constituted the attitude-toward-science scale, but it was the contribution of interest alone that was significant to the model of predictors of scientific literacy. This finding suggested that, in contrast to having an interest in science, it may be more difficult for matriculants to have a positive view of the usefulness of science. National, regional, and local efforts (e.g., by professional science societies, scientists, museums, schools, teachers, broadcast media, etc.) designed to address the usefulness of science for society and individuals therefore appear to be an important means of predisposing matriculants to achieving scientific literacy. The importance of science club membership as a predictor of the scientific literacy of White and Indian students would also seem to be related to this argument.

The evidence for the importance of the influence on scientific literacy of home environment variables was indirect, but the importance of home environment for scientific literacy is consistent with general results obtained earlier, and with other studies related to science achievement. It is interesting to note that once important school variables had been included in the respective models, the influence on the students' scientific literacy of all home environment variables other than academic home resources and family structure was not statistically significant. Although this result may be related to the possible inadequacy of investigating complex interactions with self-reported retrospective data (or it may be a consequence of the purposeful manner in which the models were constructed), the results suggest a greater relative importance of school as opposed to home environment variables for scientific literacy. As school environment variables are more amenable to direct intervention (e.g., by science educators) than home environment variables, the findings are useful in suggesting a number of recommendations to improve levels of scientific literacy of matriculants (see below).

An advantage of the regression method used in this study is that the probability of being scientifically literate is easily calculated by the estimated coefficient of the variables included in the logistic regression models. As in the South African context the overall matric result of individuals is not always a reliable indicator of their academic ability, it has been suggested earlier that the TBSL may be potentially useful for alternative or supplementary admission and placement procedures for students wishing to commence studies in science and engineering at universities and technikons. Data on the variables included in the regression model of both groups of matriculants are clearly quicker and cheaper to obtain than administering the TBSL to prospective first-year students. Investigating the relationship between the

predicted probability of students being scientifically literate and their academic performance at the end of, say, the first year of tertiary study, thus represents a highly relevant direction for further research.

A last point. Logistic regression analysis has allowed the identification of important variables that have an influence on the scientific literacy of a select group of South African matriculants. Although this technique is appropriate for the investigation of the relative influence of categories *within* variables (e.g., science subject combination), this approach is problematic in the determination of the relative influence of several variables associated with scientific literacy (e.g., home environment and gender). Scientific literacy is a complex concept, and in order to enhance the general understanding of the relationships between scientific literacy and variables related to student, school, and home, it would be valuable if the relative effects between such variables and scientific literacy were to be examined, if the relationship between school and home environment variables in the context of scientific literacy is to be fully understood.

## CONCLUSIONS

This exploratory study represents the first systematic, large-scale survey of scientific literacy of a substantial sample of matriculants at the secondary/tertiary education interface in South Africa. Underpinning the survey is the development of a unique criterion-referenced test instrument - the *Test of Basic Scientific Literacy* (TBSL) - which was constructed and validated specifically for the South African context.

This study breaks new ground in the development of a pool of scientific literacy test-items based on selected agreed-upon and explicit guidelines, which have been recommended by the American Association for the Advancement of Science, on what every high-school leaver should know in order to be regarded as scientifically literate. The approach used in the development of the test-item pool is essentially complementary to the current research framework used for national and cross-national surveys of scientific literacy, but attempts to eliminate some of the previously identified limitations of this approach for use in financially less well supported surveys. The TBSL, in turn, was constructed from discriminating test-items carefully selected from the test-item pool on the basis of empirical evidence obtained from a pilot test, and was shown to be reliable and valid for classifying South African matriculants into categories of scientific literacy and illiteracy. The scientific literacy test-item pool and the TBSL represent a new resource and tool for assessing scientific literacy, and therefore expand the data-gathering options available to researchers for conducting surveys of the increasingly important concept of scientific literacy.

This exploratory study of matriculants entering universities and technikons in the Western Cape also breaks new ground in that it provides insights about a group of important individuals about whom no

information with respect to scientific literacy was hitherto available. In this study, levels of scientific literacy were described with respect to demographic variables, as well as with respect to student background variables related to the individuals' school and home environment. Throughout this survey, it was attempted not only to describe patterns but also to provide explanations for the observed trends. Although patterns of scientific literacy levels with respect to the majority of variables were similar within population groups, overall levels of scientific literacy were found to reflect the hierarchy of inequality and discrimination due to educational and social policies present until very recently in South Africa. In general, patterns of scientific literacy levels were found to follow hypothesised trends in this study. Although some general conclusions of the study with respect to levels of scientific literacy are not novel and have been stated before in contexts related to general science achievement, this study has confirmed generally held beliefs that variables such as, for example, interest in science and the science subjects taken in the senior secondary phase, have an important impact on the scientific literacy of matriculants.

The findings of this study have generated a number of hypotheses and research questions which provide important directions for further research in both the South African, as well as in a general, context related to scientific literacy and science education. Carried out in the immediate post-apartheid era, the study provides unique baseline-data which may be used to assess the impact on scientific literacy of improved provision of education and the changed socio-economic priorities currently being implemented in South Africa.

Based on careful extrapolation of scientific literacy levels obtained from the sample, it is speculated that the science education provided by the South African education system to White students is likely to be regarded as reasonably acceptable, whereas that available to African and Coloured matriculants does not reach even minimally acceptable levels. In the light of the above findings, a number of recommendations for improving the level of scientific literacy of matriculants in South Africa are suggested in the next section.

## **SUGGESTIONS FOR THE WAY FORWARD**

In various countries a number of initiatives that are designed to increase the scientific literacy of the general public have been put into effect (e.g., Nelson, 1994), and the suggestions that follow reflect some of these initiatives. The suggestions are, however, not designed to represent an exhaustive list and instead should be seen as stimulating further discussions about measures that could be taken in order to achieve widespread scientific literacy in South Africa. The suggestions are directed at the national level as well as the school environment, and therefore do not only address the improvement of scientific literacy of matriculants but also that of the general public.

As Tindimubona (1991, p. 542) has stated, "[i]t is imperative ... for the rapid development of African peoples' social, intellectual and material culture, that science be made part and parcel of the social life of the people". In the light of the findings of this study with respect to the importance of an exposure to a culture of science for achieving scientific literacy (e.g., interest in science, parents with a science-related occupation, science-related holiday-job, science club membership, etc.), the establishment of a science culture amongst all South Africans would seem to be an intuitively obvious recommendation. A number of suggestions for achieving such a culture in Africa have been discussed before (e.g., Jugessur, 1995; Tindimubona, 1991), and the broad recommendations made here are essentially concerned with achieving national awareness of the importance of science (and science education) and address the involvement of scientists and the mass media in this process.

Although the general role of science and science policy in addressing the social upliftment of all South Africans has been politically acknowledged and supported by the recent publication of a *Green Paper on Science and Technology* (DACST, 1996), there has been no overall attempt by the government to stimulate widespread national awareness and appreciation of the importance of science in the socio-economic development process. What is therefore recommended is that an exercise similar to the one currently being carried out in the United Kingdom be conducted urgently in South Africa. In the *Science Education for the Year 2000 and Beyond* initiative, the U.K. Association for Science Education attempts to identify a new rationale for how science should be taught (Ramsden, 1995). In a wide-ranging consultative phase the association has asked all interested parties to provide it with workshopped answers to such questions as "What is science?", "Why teach science?", and "What science should be taught?", in addition to questions addressing how science should be taught (Ramsden, 1995, 1996). The association has designed a resource pack with suggested background readings and activities for each of the eight questions asked (Ramsden, 1995). A national exercise covering the first two questions would start the sensitisation process for the general South African public with respect to the role of science in their life, as well as in the wider national context. (The relevance of such an exercise for curriculum development is addressed below.)

In order to achieve a science culture, science and its relevance to society will need to be constantly highlighted. National and regional events such as, for example, science festivals would play an important part in this process, and organised science and industry will need to be encouraged to participate and take the lead in such developments. South Africa's first National Festival of Science and Technology is planned to take place in April 1997 (personal communication, Eve Cambrey, 26 July 1996), and it is recommended that this event become an annual occurrence. A further option designed to sensitise communities to the relevance of science in their lives would be to conduct small-scale regional or local science exhibitions at, for example, community centres throughout South Africa.

Individual scientists will, no doubt, be involved in such science festivals. However, individual scientists should also be encouraged to disseminate their work regularly to an interested but lay audience,



as this will undoubtedly contribute to a more pronounced awareness of science by the general public. The announcement last year by the South African Foundation for Research Development (FRD) - the major agency funding research in science in South Africa - that proposed research plans submitted for possible funding are required to address how the findings will be disseminated in order to contribute to public understanding of science, is a welcome beginning. (The impact of this initiative will, however, depend on how seriously the FRD takes this stipulation in evaluating annual and final research reports and, by implication, how it will allocate further funds to scientists who do not fulfil this requirement.)

Publishing in the print media (e.g., newspapers) and giving interviews to the broadcast media would help to accomplish the dissemination of research findings and approaches to a lay audience. To this end, South African scientists will need to acquire the necessary skills to, for example, adapt to the writing style of newspaper articles as well as deal with being interviewed. The workshop on *Media Skills in Science* conducted at the University of Stellenbosch in September 1995 is a welcome first step in this direction.

As indicated above, the mass media naturally also has a role to play in the development of scientific literacy of individuals. One "... hopes that increasing science coverage in the press and broadcast media will help de-mystify science for the public, create a pro-science feeling among readers and listeners, [and] raise public scientific literacy ..." (Laing, 1988, p. 356). No work has been carried out with respect to science coverage in the print media in South Africa, and most newspapers articles related to "science" are in fact covering the environment and not pure science (personal communication, George Claassen, 26 July 1996). The indifference with which the print media regard science journalism is made clear by the fact that out of 15 daily and eight weekly newspapers in South Africa, only one employs a full-time science reporter (who covers mainly environmental issues) (personal communication, George Claassen, 26 July 1996). Many of the problems identified by Laing (1988) and Jugessur (1995) with respect to improving the presentation of news and information about science and technology in the mass media in Africa also apply to South Africa, and it is recommended that the role of the print media in promoting scientific literacy be urgently re-examined in this country. The role of the broadcast media in contributing to this goal should be similarly investigated, and the establishment of public broadcasting (in both radio and television) as a tool for education, dedicated in part to raising the profile of science in South African communities, should be debated.

Whereas the above set of recommendations has concentrated on initiatives that could be undertaken to create a more widespread culture of science amongst all South Africans, the second set of recommendations is concerned with how the level of scientific literacy of high-school leavers could be raised. The suggestions address how pupils' interest in science may be raised, and cover science clubs, science subjects and science curricula. (Given the South African educational context, an improved

provision of science education - particularly for historically disadvantaged Black pupils - is taken for granted, and will not be further addressed here.)

High-school pupils' interest in science is likely to be stimulated or inhibited by the kind of activities and approaches that science teachers employ. It is therefore recommended that teachers become aware of the effect their teaching style(s) may have on their pupils. Science teachers should ideally include innovative and challenging teaching strategies in their teaching repertoire that convey to their pupils the beauty of science, as well as the relevance of science to everyday life. In addition, issues-based teaching strategies (e.g., using an STS approach) will influence the pupils' interest in science positively, and may also benefit their scientific literacy more directly (e.g., Yager, 1993). Moreover, integrating the history of science and technology into the science curriculum (e.g., Bybee et al., 1991) is very likely to facilitate this process. These recommendations have clear implications for initial as well as inservice teacher education, as science teachers will need to be made familiar with appropriate teaching techniques and approaches, as well as with appropriate classroom materials, that will achieve the above objectives.

Linked to interest in science is the pupils' participation in science clubs at school. Given the substantial effect of science club membership on the scientific literacy of matriculants, the establishment of a science club in *all* high schools would seem to be an important and potentially far-reaching recommendation, and high-school pupils should be strongly advised to participate in their school's extra-mural science activities. Local and regional efforts supported by parents and by, for example, industry, should be initiated to help teachers get such clubs off the ground, and science club networks should be formed. These local networks could then be used as facilitating networks and fora to exchange ideas and to discuss common problems. Such fora could also be used to pool resources (e.g., the purchase of comparatively more expensive equipment) and to share the organisation of larger events (e.g., excursions or a series of guest speakers). Moreover, establishing school-industry links may be helpful in exposing pupils to science and technology in the workplace, creating holiday-job opportunities, and identifying role models in science and technology.

In the context of the current science curricula (but see below), Physical Science is recommended to be the science subject of first choice for all senior secondary high-school pupils. This recommendation has wide-ranging implications for teacher training, as there is a general shortage of qualified Physical Science teachers in South Africa (EduSource, 1993; FRD, 1993). National efforts designed to remedy this situation will therefore need to be initiated as a matter of urgency.

In the current South African educational context, however, the principal role of the two main science subjects taken in the senior secondary phase (i.e., Physical Science and Biology) is essentially that of subjects required for university entrance, and this fact has meant that the subjects have assumed the same characteristics of most such subjects world-wide (Spargo, 1995a). The subjects place a heavy stress on theory rather than application, and the wider social, moral, and ethical consequences of science are for the most part ignored (Spargo, 1995a). Given that only between 15% to 28% of the total number of

pupils entering primary school in South Africa are estimated to enter universities or technikons after 12 years of schooling (NEPI, 1992; Watson, 1990) (estimates are, however, very much population group dependent [e.g., NEPI, 1992]), one needs to ask whether the current science subjects are in fact relevant and appropriate for the majority of South Africa's high-school leavers (cf., Millar, 1996). If a goal of science education is to produce scientifically literate matriculants or to increase the scientific literacy of *all* high-school leavers, then the objectives of science subjects in South Africa will need to be revised in order to make them more appropriate to the needs of students not planning to enter tertiary education (cf., Millar, 1996). This could be achieved by offering a different science subject to the latter group of students (e.g., "Senior General Science" [Spargo, 1995a]), but a more fundamental revision of science education may be required in order to effectively address the changing priorities of a post-apartheid South Africa.

Since the early 1990s, a number of science education policy alternatives for South Africa have been proposed (Kahn, 1995). The necessity for new science curricula has generally been acknowledged, and participatory curriculum development is seen to be central to this process (Kahn, 1995). The need for revised science curricula therefore affords this country a valuable opportunity to carry out an exercise similar to the *Science Education for the Year 2000 and Beyond* initiative (Ramsden, 1995) mentioned above. (A more wide-ranging but related endeavour is the establishment of the National Science Education Standards in the United States [e.g., Collins, 1995].) An initiative in which nation-wide answers to questions such as "What is science?", "Why teach science?", "How do children learn science and how should science be taught?", "How does science education contribute to the development of attitudes?", and so forth (Ramsden, 1996) are sought, represents a unique opportunity for post-apartheid South Africa to examine - and most likely redefine - the perceived purpose and value of science in its education system (see, for example, Spargo, 1995b). It is believed that the purpose (e.g., aims and objectives) and structure (e.g., approaches and content) of science education will be better matched as a result of such a process, and it is therefore strongly suggested that a similar endeavour be undertaken in order to achieve widespread scientific literacy in South Africa.

## CONCLUDING REMARKS

It is an implicit objective of this study - presumably not too dissimilar to much other research in the social sciences - that the data and findings presented here will hopefully be useful to and have some influence on government action and the improvement of public policy. However, it would be unreasonable and naive to believe that government decision-makers would use any one research study to shift policy in a linear manner from Policy A to Policy B (Weiss, 1995). Research has revealed that there

are four main functions that social science serves for government officials in the United States (Weiss, 1989; cited in Weiss, 1995). Studies in the social sciences were shown (a) to provide support and reinforcement for what officials believe anyway, and research findings were used to justify existing positions; (b) to provide a warning by describing conditions that are beyond the zone of acceptability; (c) to offer guidance on what action government should take; and (d) to serve as enlightenment, that is to provide officials with a background of ideas, concepts, and information that increase the official's understanding of the terrain. The specific fate of social sciences research in different countries (i.e., the extent of its influence on government action) is of course dependent on the nature of problems on the public agenda and on country-specific attributes (e.g., structures of government) (Wagner, Weiss, Wittrock, & Wollman, 1991). Given the common sense nature of the above-mentioned four main functions, and given that it is too soon after the elections for data to be available on the relationship between social science research and government action in post-apartheid South Africa (personal communication, Johann Muller, 29 July 1996), it seems reasonable to assume that the usefulness of social science research for policy formation is perceived by the relatively recently appointed South African government officials in a similar manner to the four main functions identified earlier.

It is therefore hoped that this study of the scientific literacy of matriculants entering major tertiary educational institutions in the Western Cape will not only have contributed in an academic but also in some general manner to how the challenges of widespread scientific literacy in South Africa are perceived and thought about.



## **Printed Appendices**

# **Appendix A**

## **SENTENCE VALIDATION OF *SCIENCE FOR ALL AMERICANS* TEXT**

## INSTRUCTIONS

Please proceed as follows:

1. Read a paragraph of text in the chapter, then identify what you believe to be the sentence or sentences containing the key idea(s) of undisputed significance in current science in the paragraph.
2. Ensure that each sentence chosen contains only ONE key idea - you may have to break up a sentence into multiple ones, each containing its own key idea.
3. Compare your choice of sentence(s) with mine, and then either:
  - a) confirm (C) my choice of sentence, or
  - b) confirm my choice of sentence but modify (M) the wording on the print-out directly, or
  - c) reject (R) my choice of sentence in its entirety and substitute with your own numbered sentence, written on the print-out directly or on another sheet of paper if necessary.

Please ring the appropriate letter, i.e. C, M or R, in front of the sentence to indicate your choice! Should you wish to add a sentence, simply number it (a, b, c, etc.) and insert it in the relevant paragraph on the print-out.

A dash (--) indicates that no key idea was found in that particular paragraph. The bracketed number after every sentence identifies its location in each paragraph. The "P" indicates that paraphrasing occurred, i.e. at least one word in the original sentence was changed or left out.

4. Once the complete chapter has been read and all the key ideas have been identified, please place each sentence (whether my or your own choice) into the following categories of importance:
  - a) very important (VI),
  - b) important (I), and
  - c) relatively less important (RLI).

Please ring the appropriate letter(s) after the sentence to indicate your choice!

**Thank you very much for your time and effort!**  
**I would value any comments or suggestions that you may have.**



6.1. Human identity

C	M	R	1	In most biological respects, humans are like other living organisms. (1)	VI	I	RLI
C	M	R	2	Fossil and molecular evidence supports the belief that the human species evolved from other organisms. (P 1)	VI	I	RLI
C	M	R	3a	Despite external differences, all humans are a single species. (P 1,3)	VI	I	RLI
C	M	R	3b	Humans' complex languages, technologies, and arts distinguish them from any other species. (P 5)	VI	I	RLI
C	M	R	4	Humans have a much greater range of social behavior than other species. (P 1,2)	VI	I	RLI
C	M	R	5	One of the most important events in the history of the human species was the change from hunting and gathering to farming. (P 1)	VI	I	RLI
C	M	R	6	A variety of invented technologies have helped us make up for our biological disadvantages. (P 3,4)	VI	I	RLI

6.2. Life cycle

C	M	R	1	A human develops from a single cell, formed from the fusion of an egg cell and a sperm cell. (1)	VI	I	RLI
C	M	R	2	--	VI	I	RLI
C	M	R	3a	The death rate of infants varies greatly from place to place. (P 4)	VI	I	RLI
C	M	R	3b	The death rate of infants depends on the quality of sanitation, hygiene, prenatal nutrition, and medical care. (P 4)	VI	I	RLI

## **Appendix B**

### **ITEM QUALITY REVIEW FORM**



**INSTRUCTIONS FOR USING THE "QUALITY REVIEW FORM FOR TEST-ITEMS"**

On the enclosed *Test-Item Form* are listed for each test-item the original statement (in boldface) and the corresponding true and false versions. The origin of each statement is given in round brackets, and identifies the sentence(s) within the paragraph from which the statement was taken. Each of these statements has been validated by a number of Fellows of the Royal Society of South Africa. Each test-item is identified by a unique five-digit number which describes the chapter, section, paragraph and item number per paragraph. The true and false versions are marked [T] and [F], respectively.

Please proceed as follows:

1. Read the first statement and corresponding item on the *Test-Item Form*.
2. On the attached *Quality Review Form for Test-Items*, the first question asks you to evaluate the correspondence between the original statement (in boldface) and the test-item: does the test-item substantially reflect the key or major concept expressed in the statement?
3. In the space provided on the Quality Review Form, mark

✓	for	YES,
X	for	NO,
?	for	UNSURE, and
NA	for	NOT APPLICABLE.
4. When your rating is negative (i.e. "X" or "?") for any of the questions, kindly write comments and suggested changes in wording next to the version on your copy, or on a separate sheet of paper. (Should your rating for the question 1 be negative, please ignore steps 5 to 7 below and begin the review of the next test-item.)  
**PLEASE NOTE:** Unfortunately, modifications that substantially change the content or intended meaning of the original statement are not permissible as the entire content must be derived from the AAAS publication *Science for All Americans*, where meaningful.
5. Read the TRUE version of the first test-item and answer questions 2 to 8, using the ratings and instructions in 3. and 4. above.
6. Read the FALSE version of the first test-item and answer questions 9 and 10. Then repeat the review task (i.e. questions 2 to 8) for the FALSE version.
7. The last question asks you to provide an overall evaluation of the match between the TRUE and FALSE version of each test-item. There are five possible ratings:

5 - Excellent
4 - Very Good
3 - Good
2 - Fair
1 - Poor.
8. Please repeat the entire review task for each of the remaining test-items.

**Thank you very much for your time and effort!**  
**I would value any comments or suggestions that you may have.**

# QUALITY REVIEW FORM FOR TEST-ITEMS

Test-Item Number

Characteristics of True/False Test-Item Versions

	61011		61021		61031		61032		61041		61051		61061		62011	
	T*	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F
1. Does the content of the test-item substantially correspond to the key or major concept expressed in the original statement (in boldface)?																
2. Is the TRUE version clearly true <b>scientifically</b> ?																
3. Does the version test only <b>one</b> concept or key idea?																
4. Is the version free of logical and scientific ambiguities?																
5. Is the version free of unnecessary scientific jargon?																
6. Is the version free of vocabulary and/or sentence structure which may be difficult for the great majority of students <b>entering</b> university and technikon?																
7. Will the words in the version have a common meaning for the great majority of first-year students, irrespective of background and home language?																
8. Is the FALSE version clearly false <b>scientifically</b> ?																
9. Is the FALSE version plausible and appealing to examinees who do not know the correct answer?																
10. Disregarding any technical flaws which may exist (addressed by the first 9 questions above), to what extent do you think the FALSE version is an <b>equivalent counterpart</b> to the TRUE one, each probing understanding of essentially the same concept?																

\* T = True version; F = False version

6.1. Human identity

61011 In most biological respects, humans are like other living organisms. (1)

In most *biological* respects, humans are like other living organisms. [T]

In most *biological* respects, humans are unlike other living organisms. [F]

61021 Fossil and molecular evidence supports the belief that the human species evolved from other organisms. (1)

The human species evolved from other organisms. [T]

The human species did not evolve from other organisms. [F]

61031 Despite external differences, humans are a single species. (1,3)

In spite of variations in features such as size and skin colour, humans are a single species. [T]

Because of variations in features such as size and skin colour, different humans belong to different species. [F]

61032 Humans' complex languages, technologies, and arts distinguish them from any other species. (5)

The complex languages, technologies, and arts of humans distinguish (i.e. separate) them from any other species. [T]

The complex languages, technologies, and arts of humans do not distinguish (i.e. separate) them from any other species. [F]

61041 Humans have a much greater range of social behavior than other species. (1,2)

Humans have a much greater range of social behaviour than other species. [T]

Humans have about the same range of social behaviour as other species. [F]



## **Appendix C**

### **SCIENTIFIC LITERACY TEST-ITEM POOL**





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## Appendix C

### SCIENTIFIC LITERACY TEST-ITEM POOL

The complete scientific literacy test-item pool developed in Chapter 3 (p. 43) is given below. Each item is described by a unique five-digit number. The first digit identifies the chapter in *Science for all Americans* (SFAA) (AAAS, 1989), the second identifies the subsection of the chapter, the third and fourth digits identify the paragraph within each subsection (numbered 01, 02, 03, etc.), and the fifth digit identifies the item number per paragraph. Each item consists of a True (T) and False (F) version. An asterisk identifies a version which is considered to be very much more suitable than its matched opposite. Numbers in round brackets after each True item version identify the sentence(s) (numbered 1, 2, 3, etc.) per paragraph in the original text from which the item was developed. Sentences in italics are stated as given (i.e., true) and the versions which follow refer to this true sentence.

#### ***Science for all Americans* Chapter 1: The Nature of Science (pp. 25-31)**

##### 1.1. The scientific world view

- 11011 Scientists share certain beliefs and attitudes about what they do and how they view their work. [T];(1)  
Scientists do not share beliefs and attitudes about what they do and how they view their work. [F]
- 11021 Science takes for granted that the things and events in the universe occur in consistent patterns. [T];(1)  
Science takes for granted that the things and events in the universe do not occur in consistent patterns. [F]
- 11022 Science takes for granted that patterns in the universe may be understood through careful study. [T];(1)  
Science takes for granted that patterns in the universe are hardly ever understood through careful study. [F]
- 11031 Science assumes that the basic rules about how the universe operates are the same throughout the universe. [T];(1)  
Science assumes that the rules about how the universe operates may not be the same throughout the universe. [F]
- 11041 In science, the testing, improving and discarding of theories goes on all the time. [T];(5)  
In science, the testing, improving and discarding of theories takes place only rarely. [F]
- 11051 Scientists reject the idea that we will one day know everything there is to know about the universe. [T];(1)  
Scientists accept the idea that we will one day know everything there is to know about the universe. [F]
- 11052 Scientists believe that most scientific knowledge is durable (i.e. lasts a long time). [T];(1)  
Scientists believe that most scientific knowledge does not last a long time but is ever-changing. [F]

- 11053 Normally in science ideas are modified (i.e. changed) rather than rejected outright. [T];(2)  
In science, ideas are usually rejected outright, rather than modified (i.e. changed). [F]
- 11061 There are many aspects of our lives that cannot be usefully examined in a scientific way. [T];(1)  
Any aspect of our lives can be usefully examined in a scientific way. [F]

### 1.2. Scientific inquiry

- 12011 Scientists working in different scientific fields agree about what makes a scientific investigation valid. [T];(3)  
Scientists working in different scientific fields disagree about what makes a scientific investigation valid. [F]
- 12021 There are no fixed steps that scientists always follow to lead them without fail to scientific knowledge. [T];(2)  
There are fixed steps that scientists always follow to lead them without fail to scientific knowledge. [F]
- 12022 Science has a distinctive (i.e. special) character as a way of enquiry. [T];(3)  
Science does not have a distinctive (i.e. special) character as a way of enquiry. [F]
- 12031 Sooner or later, the validity (i.e. truth) of scientific claims is settled by referring to observations of phenomena. [T];(1)  
The validity (i.e. truth) of scientific claims is seldom settled by referring to observations of phenomena. [F]
- 12041 In science, the findings of any one investigator or group are usually checked by other scientists. [T];(6)  
In science, the findings of any one investigator or group are rarely checked by other scientists. [F]
- 12051 Scientists agree about the principles of logical reasoning that connect evidence with conclusions. [T];(3)  
Scientists disagree about the principles of logical reasoning that connect evidence with conclusions. [F]
- 12061 One of the chief activities of scientists is the process of putting forward and testing hypotheses (i.e. provisional explanations). [T];(4)  
The process of putting forward and testing hypotheses (i.e. provisional explanations) is not one of the chief activities of scientists. [F]
- 12071 Science is as creative as writing poetry or composing music. [T];(3)  
Science is much less creative than writing poetry or composing music. [F]
- 12081 *Scientists try to make sense of phenomena by inventing explanations for them.*  
These explanations use currently accepted scientific principles. [T];(1)  
These explanations rarely use currently accepted scientific principles. [F]
- 12091 Scientific theories should explain additional observations that were not used in developing the theories in the first place. [T];(3)  
Scientific theories need not explain additional observations that were not used in developing the theories in the first place. [F]
- 12101 Scientific evidence can be biased (i.e. distorted) in the way that data are interpreted, recorded, reported or selected. [T];(2)  
Scientific evidence is never biased (i.e. distorted) in the way that data are interpreted, recorded, reported or selected. [F]

- 12102 Scientists may, because of their background, personal beliefs and values, look for different types of evidence. [T\*];(3)  
In spite of their background, personal beliefs and values, scientists do not look for different types of evidence. [F]
- 12103 Scientists may, because of their background, personal beliefs and values, emphasise different interpretations of evidence. [T\*];(3)  
In spite of their background, personal beliefs and values, scientists do not emphasise different interpretations of evidence. [F]
- 12111 Scientists try to identify possible bias in the work of other scientists. [T];(2)  
Scientists do not try to identify possible bias in the work of other scientists. [F]
- 12112 Scientists are expected to safeguard against possible bias in their own work. [T\*];(2)  
Scientists are not usually expected to safeguard against possible bias in their own work. [F]
- 12121 In carrying out an investigation, no scientist must be made to feel that s/he should reach a particular result. [T];(4)  
In carrying out an investigation, a scientist is often made to feel that s/he should reach a particular result. [F]
- 12131 Challenges to new ideas are an important part of science in building valid (i.e. truthful) knowledge. [T];(2)  
Accepting new ideas without challenge is a normal part of science in building valid (i.e. truthful) knowledge. [F]
- 12132 When a new or improved scientific theory is put forward which explains more phenomena than the previous theory, the new theory eventually takes the previous one's place. [T\*];(4)  
[No meaningful false version could be constructed]

### 1.3. The scientific enterprise

- 13011 Scientific activity is one of the main features of the world today. [T];(2)  
Scientific activity is a minor feature of the world today. [F]
- 13021 Scientific work (i.e. research and teaching) goes on in all nations of the world. [T];(1)  
Scientific work (i.e. research and teaching) goes on in only a few nations of the world. [F]
- 13031 Because science is an activity carried out by many different people, science must reflect values and viewpoints related to society (e.g. views on women, political beliefs). [T];(1)  
Even though science is an activity carried out by many different people, science hardly ever reflects values and viewpoints related to society (e.g. views on women, political beliefs). [F]
- 13041 The direction of scientific research (e.g. which questions are considered worth asking) is affected by informal influences within science itself. [T];(1)  
The direction of scientific research (e.g. which questions are considered worth asking) is hardly affected by informal influences within science itself. [F]
- 13051 Science does not only take place in universities and technikons, but also in business, industry, classrooms, the outdoors, etc. [T];(1,2,4)  
Science only takes place in universities and technikons, and not in either business, industry, classrooms, the outdoors, etc. [F]

- 13061 The spreading of scientific information is crucial to the progress of science. [T];(1)  
The spreading of scientific information is unimportant to the progress of science. [F]
- 13071 *Scientific fields such as archaeology and zoology differ from one another in many ways.*  
In spite of this, they are all equally scientific with respect to purpose and philosophy. [T];(3,4)  
Because of this, very few are equally scientific with respect to purpose and philosophy. [F]
- 13072 Scientific fields such as chemistry and biology do not have fixed boundaries or borders. [T];(7)  
Scientific fields such as chemistry and biology have fixed boundaries or borders. [F]
- 13081 [parallel to 13051]
- 13091 The bodies (e.g. the different government departments) which supply money for research influence the direction of science (i.e. which research to undertake). [T];(1,2)  
The bodies (e.g. the different government departments) which supply money for research seldom influence the direction of science (i.e. which research to undertake). [F]
- 13101 Because of strongly held traditions in science, most scientists behave professionally and ethically (i.e. in a moral and honest way). [T];(2)  
There are few traditions in science that result in most scientists behaving professionally and ethically (i.e. in a moral and honest way). [F]
- 13111 Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harm that could result from scientific experiments. [T];(1)  
Scientific ethics (i.e. system of morals) is not concerned with the possible harm that could result from scientific experiments. [F]
- 13121 Scientific ethics (i.e. system of morals) is concerned amongst other things with the possible harmful effects of applying the results of research. [T];(1)  
Scientific ethics (i.e. system of morals) is not concerned with the possible harmful effects of applying the results of research. [F]
- 13131 Scientists can often play an important advisory role in matters of public interest (e.g. nuclear power or conservation of the environment). [T];(1,4)  
Scientists can seldom play an important advisory role in matters of public interest (e.g. nuclear power or conservation of the environment). [F]
- 13141 Scientists can seldom bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment). [T];(1)  
Scientists can almost always bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment). [F]
- 13151 In many public matters, scientists can be expected to be biased where their own interests are at stake (e.g. building a new highway near their home). [T];(2)  
Even where their own interests are at stake, scientists can be expected to be unbiased in many public matters (e.g. building a new highway near their home). [F]

*Science for all Americans* Chapter 3: The Nature of Technology (pp. 39-45)

3.1. Science and Technology

- 13011 Scientific understanding is just as important to technology as accumulated practical knowledge. [T];(3)  
Scientific understanding is less important to technology than accumulated practical knowledge. [F]

- 31021 *Engineers use technology together with design strategies (i.e. skills) to solve practical problems.*  
 Knowledge of science is usually also used in this process of solving practical problems. [T];(4)  
 Knowledge of science is seldom used in this process of solving practical problems. [F]
- 31031 More and more, technology is developing new instruments and techniques to advance scientific research. [T];(4)  
 New instruments and techniques being developed through technology make little contribution to scientific research. [F]
- 31041 Technology does not just provide tools for science - it may also provide motivation and direction for theory and research in science. [T];(1)  
 Technology just provides tools for science - it seldom provides motivation and direction for theory and research in science as well. [F]
- 31051 As technology becomes more sophisticated (i.e. advanced), technology's links to science become stronger. [T];(1)  
 As technology becomes more sophisticated (i.e. advanced), technology's links to science remain unchanged. [F]
- 31052 New technology often needs new scientific understanding. [T];(3)  
 New technology seldom needs new scientific understanding. [F]
- 31053 New scientific investigations often need new technology. [T];(3)  
 New scientific investigations seldom need new technology. [F]
- 31061 -- (1) [No meaningful item could be constructed]
- 31071 Many scientists and engineers do work that could be described as engineering as well as science. [T];(2,3)  
 [No meaningful false version could be constructed]
- 31081 Engineers cannot design solutions for all our problems. [T];(3)  
 Engineers can design solutions for all our problems. [F]
- 31091 In the short term, engineering affects societies and cultures more directly than scientific research. [T];(1)  
 In the short term, scientific research affects societies and cultures more directly than engineering. [F]
- 31092 *Engineering decisions without fail involve scientific judgements.*  
 These decisions also involve social and personal values. [T];(2)  
 These decisions exclude (i.e. rule out) social and personal values. [F]

### 3.2. Principles of technology

- 32011 Every engineering design operates within constraints (e.g. physical laws, economics, politics) that must be identified and taken into account. [T];(1)  
 Engineering design usually does not operate within constraints (e.g. physical laws, economics, politics) that must be identified and taken into account. [F]
- 32012 *In engineering, a design takes into account all the constraints (e.g. physical laws, economics, politics).*  
 An optimum (i.e. "best") design arrives at some reasonable compromise (i.e. balance) among the different constraints. [T];(1,4)  
 An optimum (i.e. "best") design allows no compromise (i.e. balance) among the different constraints. [F]

- 32021 *Different people place different values on different constraints (e.g. physical laws, economics, politics) that act on engineering designs (e.g. a person may favour a safer but more expensive design).*  
Because of this difference in values, every engineering design problem has many alternative solutions. [T];(3)  
Because of this difference in values, every engineering design problem has very few alternative solutions. [F]
- 32031 It is not practical for engineers to design something (be it a machine or a chemical process) without considering where and how it will be used. [T];(1)  
It is practical to design something (be it a machine or a chemical process) an isolated object or process without considering where and how it will be used. [F]
- 32041 Engineering designs almost always need to be tested. [T];(1)  
Engineering designs rarely need to be tested. [F]
- 32051 All engineering systems need control to keep them operating properly, i.e. comparing information about what is happening with what we want to happen, and then making appropriate adjustments. [T];(1)  
Few engineering systems need control to keep them operating properly, i.e. comparing information about what is happening with what we want to happen, and then making appropriate adjustments. [F]
- 32061 In spite of mechanical and electronic devices, the ultimate control of technological systems lies with people who understand the control process and the context in which the control process operates. [T\*];(5)  
The ultimate control of technological systems lies with mechanical and electronic devices rather than with people who understand the control process and the context in which the control process operates. [F]
- 32071 In addition to its intended benefits, every engineering design is likely to have unintended side effects. [T];(1)  
Every engineering design will only have intended benefits and no unintended side effects. [F]
- 32081 *The effects of large numbers of relatively simple objects (e.g. refrigerators or solar cookers) may be individually small.*  
However, these effects may be collectively significant. [T\*];(2)  
[No meaningful false version could be found]
- 32091 Many side effects of new technological designs are not predictable (i.e. cannot be forecast) because of the great complexity of modern technological systems. [T\*];(1,2)  
In spite of the great complexity of modern technological systems, all side effects of new technological designs are predictable (i.e. can be forecast). [F]
- 32092 -- (4) [No meaningful item could be constructed]
- 32101 People's psychological reactions to risk (e.g. their fear of flying or driving) do not necessarily match the reality of the risks involved. [T];(3)  
People's psychological reactions to risk (e.g. their fear of flying or driving) match the reality of the risks involved. [F]
- 32111 -- (combined with 32131)
- 32121 A technological system is usually designed so that its most likely way of failing will do the least harm. [T];(1)  
A technological system is usually not designed so that its most likely way of failing would do the least harm. [F]

- 32131 No matter what precautions are taken or how much money is spent, any technological system can fail. [T];(2)  
If sufficient precautions are taken or enough money is spent, a technological system can be designed so that it cannot fail. [F]

### 3.3. Technology and society

- 33011 Social and economic forces within a country strongly influence what technologies will be developed within that country. [T];(2)  
Social and economic forces within a country have little influence on what technologies will be developed within that country. [F]
- 33021 Technology has strongly influenced the course of history. [T];(1)  
Technology has had little influence on the course of history. [F]
- 33022 Technology has strongly influenced the nature of human society. [T];(1)  
Technology has had little influence on the nature of human society. [F]
- 33031 Technological and social change influence each other. [T];(1,2)  
Technological and social change have little influence on each other. [F]
- 3304/51 Factors such as potential economic value or military applications, may restrict (i.e. limit) the free flow of technological or scientific knowledge. [T];(4.2, 5.3, 5.4)  
Factors such as potential economic value or military applications, rarely restrict (i.e. limit) the free flow of technological or scientific knowledge. [F]
- 33061 -- (P 2) [No meaningful item could be constructed]
- 33071 The relevant technical facts alone usually do not settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the decision. [T];(2)  
The relevant technical facts alone usually settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the decision. [F]
- 33081 The total effect of decisions by large numbers of individual people can influence the large-scale use of technology as much as the pressure on decisions by government can. [T];(3)  
The total effect of decisions by large numbers of individual people cannot influence the large-scale use of technology as much as pressure on decisions by government can. [F]
- 33091 Most decisions on technology-related issues have to be made using incomplete information. [T];(2)  
Most decisions on technology-related issues are made using complete information. [F]
- 33092 Technology-related decisions are likely to be influenced as much by politics as by technical factors. [T];(2)  
Technology-related decisions are unlikely to be influenced as much by politics as by technical factors. [F]
- 33093 -- (3) [No meaningful item could be constructed]



*Science for all Americans Chapter 4 (Part I): The Physical Setting (pp. 47-50)*4.1. The universe

- 41011 The earth is only about a third as old as the universe. [T];(2)  
The earth is as old as the universe. [F]
- 41012 Our sun is a star. [T];(3)  
Our sun is a planet. [F]
- 41013 Our galaxy contains many thousands of millions of stars. [T];(4)  
Our galaxy only contains a few thousand stars. [F]
- 41014 Apart from our own, the universe contains many billions of galaxies. [T];(4)  
Apart from our own, there are no other galaxies in the universe. [F]
- 41021 Light from the nearest star to our sun takes about four years to reach us. [T];(1,2)  
Light from the nearest star to our sun takes only a few minutes to reach us. [F]
- 41031 In the universe there are many other bodies similar to our sun. [T]  
In the universe there are no other bodies similar to our sun. [F]
- 41032 There are other galaxies different in size and shape from our own galaxy. [T];(3)  
All other galaxies are similar in size and shape to our own galaxy. [F]
- 41033 In other galaxies, there appear to be the same elements, forces, and forms of energy as are found in our own galaxy. [T];(3,4)  
In other galaxies, there appear to be different elements, forces, and forms of energy as are found in our own galaxy. [F]
- 41041 It seems that the entire known universe exploded into existence from a single hot, dense mass. [T];(1)  
It seems that the entire known universe has always existed in much the same form as it is today. [F]
- 41042 It seems that the entire known universe came into existence more than 10 thousand million years ago. [T];(1)  
It seems that the entire known universe came into existence no more than a few thousand years ago. [F]
- 41051 Our solar system came into existence about 5 thousand million years ago. [T];(1)  
Our solar system came into existence a few thousand years ago. [F]
- 41052 Everything in and on the earth is made of material that has originated in a giant cloud of gas and dust. [T];(1,2)  
Everything in and on the earth is made of material that has not originated in a giant cloud of gas and dust. [F]
- 41061 There are nine planets in our solar system. [T];(1)  
There are more than twenty planets in our solar system. [F]
- 41062 All planets move around our sun. [T\*];(1)  
Only a few of the planets move around our sun. [F]
- 41071 Apart from the planets, there are a great many small objects of rock and ice moving around our sun. [T];(1)  
Apart from the planets, no other objects move around our sun. [F]

- 41081 Our knowledge of the solar system and the rest of the universe is still growing. [T];(1)  
We know everything that there is to know about the solar system and the rest of the universe. [F]
- 41082 Our knowledge of the universe comes to us mostly through the use of instruments we have developed, e.g. telescopes. [T];(1)  
Our knowledge of the universe comes to us mostly by direct observation with the naked eye. [F]
- 41091 Most of our knowledge of the universe comes from looking at very small slices of space and small intervals of time. [T\*];(1)  
Most of our knowledge of the universe comes from looking at the universe as a whole. [F]

#### 4.2. The earth

- 42011 We live in the only known system of planets. [T];(1)  
We live in one of many known systems of planets. [F]
- 42012 The shape of the earth is almost spherical. [T\*];(2)  
[No meaningful false version could be constructed]
- 42013 -- (3) [No meaningful item could be constructed]
- 42014 About three-quarters of the earth's surface is covered by a layer of water. [T];(3)  
About three-quarters of the earth's surface is covered by land. [F]
- 42015 Compared to the earth's diameter, a thin blanket of air surrounds the entire earth. [T];(3)  
Compared to the earth's diameter, a very thick blanket of air surrounds the entire earth. [F]
- 42021 Of all the planets and moons in our solar system, only the earth appears able to support life as we know it. [T];(1)  
Many of the planets and moons in our solar system appear able to support life as we know it. [F]
- 42031 There is no liquid water at the surface of planets other than the earth. [T];(2)  
There is liquid water at the surface of planets other than the earth. [F]
- 42041 The earth orbits (i.e. moves around) the sun. [T];(2)  
The sun orbits (i.e. moves around) the earth. [F]
- 42042 The earth rotates (i.e. turns) on its axis. [T];(4)  
The stars rotate (i.e. turn) around the stationary earth. [F]
- 42043 The moon orbits (i.e. moves around) the earth. [T];(5)  
The earth orbits (i.e. moves around) the moon. [F]
- 42044 *The earth's axis is tilted, i.e. slanted.*  
This tilt produces seasonal changes in the earth's climate. [T];(2,3)  
This tilt has nothing to do with seasonal changes in the earth's climate. [F]
- 42051 Varying radiation from the sun is the basic cause of changes in climate on earth. [T];(3)  
Varying radiation from the earth's hot interior is the basic cause of changes in climate on earth. [F]
- 42061 *Water continuously moves in and out of the atmosphere.*  
This plays an important role in determining patterns in climate on earth. [T];(1)  
This plays an extremely small role in determining patterns in climate on earth. [F]

- 42071 The earth's climate has changed a lot over thousands of years. [T];(1)  
The earth's climate has changed very little over thousands of years. [F]
- 42072 The earth's climate is expected to change over thousands of years. [T];(1)  
The earth's climate is expected to remain the same over thousands of years. [F]
- 42081 *The earth has many resources of great importance to human life.*  
Some resources can be readily renewed, some can be renewed only at great cost, and some cannot be renewed at all. [T\*];(1,2)  
All these resources can be equally renewed. [F]
- 42091 Fresh water is an essential resource for daily life. [T];(1)  
Fresh water is a non-essential resource for daily life. [F]
- 42092 Fresh water is an essential resource for industrial processes. [T];(1)  
Fresh water is a non-essential resource for industrial processes. [F]
- 42101 The oceans and atmosphere can only be changed by a limited amount before affecting human activities unfavourably. [T];(4,5)  
The oceans and atmosphere can be changed by an unlimited amount without affecting human activities unfavourably. [F]

#### 4.3. Forces that shape the earth

- 43011 Forces within the earth affect its surface. [T];(2)  
Forces within the earth do not affect its surface. [F]
- 43021 *The earth's minerals (e.g. quartz, asbestos) are formed, dissolved, and reformed.*  
These processes take place on the earth's surface, in the oceans, and in the layers beneath the earth's crust. [T];(4)  
These processes take place only in the layers beneath the earth's crust. [F]
- 43031 Wind and water, in its various forms, change the earth's surface to produce distinctive landforms (e.g. mountains, valleys, etc.). [T\*];(1)  
Only wind changes the earth's surface to produce distinctive landforms (e.g. mountains, valleys, etc.). [F]
- 43041 *Elements such as carbon, oxygen, nitrogen, and sulphur, move slowly through the land, oceans, and atmosphere.*  
While doing so, elements change their chemical combinations. [T];(1)  
While doing so, elements do not change their chemical combinations. [F]
- 43051 The presence of life has altered the earth's atmosphere. [T];(3)  
The earth's atmosphere has been unaltered by the presence of life. [F]
- 43061 The landforms (e.g. mountains, valleys, etc.), climate, and resources of the earth's surface affect where and how people live. [T];(1)  
The landforms (e.g. mountains, valleys, etc.), climate, and resources of the earth's surface have little affect on where and how people live. [F]
- 43062 Human activities have changed the earth's land surface, oceans, and atmosphere. [T];(2)  
Human activities have hardly changed the earth's land surface, oceans, and atmosphere. [F]

*Science for all Americans Chapter 4 (Part II): The Physical Setting (pp. 51-56)*4.4. The structure of matter

- 44011 All things of the physical world are made up of different combinations of about 100 chemical elements. [T\*];(1,3,4)  
Not all things of the physical world are made up of different combinations of about 100 chemical elements. [F]
- 44021 There are one or more different kinds of atoms for each of the chemical elements. [T];(2)  
There is only one kind of atom for each of the chemical elements. [F]
- 44022 Apart from the pure elements, all substances consist of atoms from different elements joined together. [T\*];(free, using 1)  
[No false version seems appropriate]
- 44031 Depending on temperature and pressure, every substance can exist in a number of different states (i.e. solid, liquid, or gas). [T];(1)  
The number of different states (i.e. solid, liquid, or gas) that every substance can exist in has nothing to do with temperature and pressure. [F]
- 44041 At extremely high temperatures nuclei of atoms may join together (i.e. fuse). [T];(2)  
At extremely low temperatures nuclei of atoms may join together (i.e. fuse). [F]
- 44051 The way atoms bond together is determined by the arrangement of the outermost electrons in each atom. [T];(1)  
The way atoms bond together is determined by the arrangement of *all* the electrons in each atom. [F]
- 44061 -- (1) [Same principle as 44051]
- 44071 A low level of background radiation exists naturally in the general environment (i.e. the world around us). [T];(5)  
There is no natural radiation in the general environment (i.e. the world around us). [F]
- 44081 *Radioactive nuclei are unstable and eventually disintegrate.*  
One cannot predict when a particular unstable nucleus will disintegrate. [T];(1,2)  
One can predict when a particular unstable nucleus will disintegrate. [F]

4.5. Transformations of energy

- 45011 In the universe, energy appears in many forms. [T];(1)  
In the universe, energy appears only in one particular form. [F]
- 45012 Most of what happens in the universe - such as the collapsing of stars, biological growth, the operation of machines - involves one form of energy being changed into another form. [T];(3)  
Very little of what happens in the universe involves one form of energy being changed into another form. [F]
- 45021 Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by an equal amount. [T];(3)  
Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by a larger amount. [F]

- 45031 The total amount of useful energy in a system, such as an electric hot-water tank, is decreasing unless it is continuously supplied with electricity. [T];(3)  
The total amount of useful energy in a system such as a switched-off electric hot-water tank always remains the same. [F]
- 45041 When atoms or molecules interact, they will usually end up in less order than they began with. [T];(5)  
When atoms or molecules interact, they will usually end up in more order than they began with. [F]
- 45051 The *total* amount of disorder in the matter making up the universe is increasing. [T];(4)  
The *total* amount of order in the matter making up the universe is increasing. [F]
- 45061 Different energy levels of molecules are associated with different arrangements of atoms in molecules. [T];(1)  
Arrangements of atoms in molecules are unrelated to different energy levels of the molecules. [F]
- 45071 Energy as well as matter occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms. [T];(1)  
Matter, but not energy, occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms. [F]
- 45081 Reactions in the nuclei of atoms involve far greater energy changes than those between the outer electrons of atoms. [T];(1)  
Reactions between the outer electrons of atoms involve far greater energy changes than reactions in the nuclei of atoms. [F]

#### 4.6. The motion of things

- 46011 Nothing in the universe - from atoms to living things to stars - is at rest, but is always moving relative to something else. [T];(3)  
Most things in the universe - whether atoms, living things, or stars - are at rest, and are not moving relative to something else. [F]
- 46021 All motion is relative to whatever point or object we choose. [T\*];(2)  
There is a point or objective in space that can serve as a single, absolute reference for something that is actually moving. [F]
- 46031 Changes in motion are always due to the effects of unbalanced forces. [T];(1,2)  
Unbalanced forces play no role in changes in motion. [F]
- 46041 -- (P 1) [No meaningful item could be constructed]
- 46051 On the earth's surface, vibrations set up a travelling disturbance that spreads away from its source. [T\*];(1)  
[no meaningful false version could be constructed]
- 46061 The observed wavelength of a wave depends in part upon the relative motion of the source of the wave with respect to the observer. [T];(1)  
The observed wavelength of a wave is independent of the relative motion of the source of the wave with respect to the observer. [F]
- 46071 The interaction between waves and matter can be greatly influenced by the wavelength of the wave. [T];(1)  
The interaction between waves and matter is not influenced by the wavelength of the wave. [F]

- 46081 Materials that allow one range of wavelengths of electromagnetic radiation (e.g. visible light, ultraviolet light, X-rays) to pass through them may completely absorb other ranges. [T];(1)  
Materials that allow one range of wavelengths of electromagnetic radiation (e.g. visible light, ultraviolet light, X-rays) to pass through them, allow all other ranges of wavelengths to pass through them. [F]
- 46091 Things appear to have different colours because they reflect or scatter visible light of some wavelengths more than others. [T\*];(3)  
[No false version seems appropriate]

#### 4.7. The forces of nature

- 47011 Every object in the universe exerts gravitational forces on every other object. [T];(2)  
Every object in the universe exerts gravitational forces on nearby objects only. [F]
- 47021 The *electromagnetic* forces acting between atoms are vastly stronger than the *gravitational* forces acting between them. [T];(1)  
The *electromagnetic* forces acting between atoms are about as strong as the *gravitational* forces acting between them. [F]
- 47031 How materials conduct electricity depends on how many of the electric charges in them are free to move. [T];(1)  
How materials conduct electricity is unrelated to the number of electric charges in them that are free to move. [F]
- 47041 Magnetic forces are very closely related to electric forces. [T];(1)  
Magnetic and electric forces are unrelated to one another. [F]
- 47051 A changing electric field produces a magnetic field. [T];(2).  
A changing electric field does not produce a magnetic field. [F]
- 47061 Some forces operate only inside the nucleus of an atom. [T];(1)  
No forces operate only inside the nucleus of an atom. [F]

### *Science for all Americans Chapter 5: The Living Environment (pp. 59-64)*

#### 5.1. Diversity of life

- 51011 *Biologists classify organisms into groups and subgroups.*  
This is done on the basis of similarities and differences in the structure and behaviour of the organisms. [T];(2)  
This is done in a manner that is unrelated to the structure and behaviour of the organisms. [F]
- 51021 When scientists classify organisms, they consider anatomy (i.e. structure) to be more important than behaviour and appearance. [T];(2)  
When scientists classify organisms, they consider behaviour and appearance to be just as important as anatomy (i.e. structure). [F]
- 51031 Biological classification systems are theoretical frameworks created by biologists for describing the great diversity of organisms. [T];(3,4)  
Biological classification systems are not created by biologists but are part of nature. [F]

- 51032 Biological classification systems suggest relationships among living things. [T];(4)  
Biological classification systems do not tell us anything about relationships among living things. [F]
- 51041 *In living organisms, most complex molecules are chains of smaller molecules.*  
In each species, there are characteristic sequences of small molecules that make up complex molecules. [T];(1)  
In each species, there are no characteristic sequences of small molecules that make up complex molecules. [F]
- 51051 Keeping a great variety of species on earth is important to human beings. [T];(1)  
Keeping a great variety of species on earth is unimportant to human beings. [F]
- 51052 Human beings depend on food webs (i.e. interlinked food chains) to obtain the energy and materials necessary for life. [T];(2)  
In obtaining the energy and materials necessary for life, human beings are independent of food webs (i.e. interlinked food chains). [F]
- 51053 Maintaining relatively large populations of a great variety of species increases the chance that some individuals of some species will be able to survive under changed conditions, e.g. climate. [T];(8)  
Maintaining relatively large populations of a great variety of species has no influence on the chance of some individuals of some species surviving under changed conditions, e.g. climate. [F]

## 5.2. Heredity

- 52011 Offspring (i.e. young) always differ in some respects from their parents. [T];(1)  
Offspring (i.e. young) are identical to their parents. [F]
- 52012 Offspring (i.e. young) differ in some respects from one another. [T];(1)  
Offspring (i.e. young) are always identical to one another. [F]
- 52021 Instructions for development from egg to adult are passed from parents to offspring (i.e. young) in many thousands of genes. [T];(1)  
Instructions for development from egg to adult are passed from parents to offspring (i.e. young) in a few hundred genes. [F]
- 52022 Each gene is one - or more than one - particular segment of a molecule of DNA. [T];(1)  
Each gene is one - or more than one - particular segment of a molecule of protein. [F]
- 52031 The "mixing" of genes in sexual reproduction results in a great variety of gene combinations among the offspring (i.e. young) of two parents. [T];(1)  
The "mixing" of genes in sexual reproduction results in only a tiny variety of gene combinations among the offspring (i.e. young) of two parents. [F]
- 52041 New "mixes" of genes as a result of sexual reproduction are not the only source of variation in the characteristics of organisms. [T];(1)  
New "mixes" of genes as a result of sexual reproduction are the only source of variation in the characteristics of organisms. [F]
- 52042 Sometimes some of the "information" in a cell's DNA is changed. [T];(2)  
The "information" in a cell's DNA always remains the same. [F]

5.3. Cells

- 53011 All life-forms on earth are made up of cells. [T];(1)  
Only some life-forms on earth are made up of cells. [F]
- 53012 Many of the basic functions of organisms, such as extraction of energy from nutrients, are carried out at the level of the cell. [T];(3)  
[No meaningful false version could be constructed]
- 53021 -- (P 1) [No meaningful item can be constructed]
- 53031 The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. [T];(1)  
The genetic information encoded in DNA molecules plays no role in the assembly of protein molecules. [F]
- 53041 The function or work of the cell is carried out mostly by different types of protein molecules. [T];(1)  
The function or work of the cell is rarely carried out by different types of protein molecules. [F]
- 53051 The chemical processes in the cell are controlled from both inside and outside the cell. [T];(2)  
The chemical processes in the cell are controlled from inside the cell only. [F]
- 53061 *Most organisms have many different cells.*  
In such organisms, most cells perform some special functions that other cells do not. [T];(1,2)  
In such organisms, most cells perform only the basic functions common to all cells. [F]

5.4. Interdependence of life

- 54011 In an ecosystem, every species depends, directly or indirectly, on all other species in that system. [T];(1)  
In an ecosystem, species are usually independent of every other species. [F]
- 54021 -- [No key idea was found]
- 54031 In an ecosystem, life-forms interact with one another and with the environment. [T];(6)  
In an ecosystem there are few interactions either between life-forms or between life-forms and the environment. [F]
- 54032 To understand well any one part of an ecosystem, we need to know how that part of the ecosystem interacts with the other parts of the ecosystem. [T\*];(6)  
To understand well any one part of an ecosystem, we do not need to know how that part of the ecosystem interacts with the other parts of the ecosystem. [F]
- 54041 The interdependence of organisms in an ecosystem often results in an almost stable system over very long periods of time. [T];(1)  
The interdependence of organisms in an ecosystem results in very little stability over a very long time. [F]
- 54051 Ecosystems tend to show cyclic fluctuations around a state of near equilibrium. [T];(1)  
Ecosystems tend to show random fluctuations around a state of near equilibrium. [F]
- 54052 Ecosystems cannot avoid changing when the climate changes. [T];(2)  
Ecosystems remain constant even when the climate changes a great deal. [F]



- 55053 Ecosystems cannot avoid changing when very different new species appear. [T];(2)  
Ecosystems remain constant even when very different new species appear. [F]

### 5.5. Flow of matter and energy

- 55011 Living organisms share with all other natural systems the same principles of the conservation of matter and energy. [T];(1)  
Living organisms do not share with other natural systems the same principles of the conservation of matter and energy. [F]
- 55021 Almost all life on earth is basically maintained by transformations of energy from the sun. [T];(1)  
Only a small proportion of life on earth is basically maintained by transformations of energy from the sun. [F]
- 55031 The elements that make up the molecules of living things are continuously recycled. [T];(1)  
The elements that make up the molecules of living things are not recycled. [F]
- 55041 Coal and oil were formed millions of years ago. [T];(1,2)  
Coal and oil were formed thousands of years ago. [F]
- 55042 Coal and oil were formed from organic material. [T];(1,2)  
Coal and oil were formed from inorganic material. [F]
- 55043 *Carbon dioxide was removed from the atmosphere over millions of years.*  
By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at a much faster rate than at which it was removed from the atmosphere. [T];(5)  
By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at approximately the same rate at which it was removed from the atmosphere. [F]
- 55051 The amount of life any environment can support is limited by its most basic resources. [T];(1)  
The amount of life any environment can support is unlimited. [F]

### 5.6. Evolution of life

- 56011 The earth's present-day life-forms have evolved from common ancestors over many millions of years. [T];(1)  
The earth's present-day life-forms have always existed in their present form. [F]
- 56021 *The fossil record stretches back over millions of years.*  
Since the beginning of the fossil record, huge numbers of new life-forms, such as species, have appeared. [T];(1)  
Since the beginning of the fossil record, only small numbers of new life-forms, such as species, have appeared. [F]
- 56022 *The fossil record stretches back over millions of years.*  
Since the beginning of the fossil record, most old life-forms, such as species, have disappeared. [T];(1)  
Since the beginning of the fossil record, most old life-forms, such as species, have remained in existence. [F]
- 56031 Life on earth has existed for about three thousand million years. [T];(2)  
Life on earth has existed for only a few thousand years. [F]

- 56041 The result of natural selection is that over successive generations within any species, the proportion of individuals that have inherited advantage-giving characteristics will tend to increase. [T];(1,2)  
The result of natural selection is that over successive generations within any species, the proportion of individuals that have inherited advantage-giving characteristics will remain the same. [F]
- 56051 Natural selection can act upon biochemistry, anatomical features and behaviour. [T];(1,3)  
Natural selection cannot act upon biochemistry, anatomical features and behaviour. [F]
- 56061 New combinations or mutations of parents' genes can result in new characteristics which can be inherited. [T];(1)  
New combinations or mutations of parents' genes do not result in new characteristics which can be inherited. [F]
- 56071 Natural selection is likely to lead to organisms with characteristics that are well adapted to survival in particular environments. [T];(1)  
Natural selection is unlikely to lead to organisms with characteristics that are well adapted to survival in particular environments. [F]
- 56072 Natural selection does not *necessarily* result in increasingly greater advantages of characteristics of an organism. [T];(4)  
Natural selection always results in increasingly greater advantages of characteristics of an organism. [F]
- 56081 Evolution is not a ladder in which the lower life-forms are all replaced with superior forms. [T];(2)  
Evolution is a ladder in which the lower life-forms are all replaced with superior forms. [F]
- 56082 Evolution is not a ladder with humans finally emerging at the top as the most advanced species. [T];(2)  
Evolution is a ladder with humans finally emerging at the top as the most advanced species. [F]
- 56091 The modern concept of evolution provides a unifying principle for understanding the history of life on earth. [T\*];(1)  
The modern concept of evolution does not provide a unifying principle for understanding the history of life on earth. [F]

*Science for all Americans Chapter 6: The Human Organism (pp. 67-74)*

6.1. Human identity

- 61011 In most *biological* respects, humans are like other living organisms. [T];(1)  
In most *biological* respects, humans are unlike other living organisms. [F]
- 61021 There is much evidence that the human species evolved from other organisms. [T];(1)  
There is little evidence that the human species evolved from other organisms. [F]
- 61031 In spite of variations in features such as size and skin colour, humans are a single species. [T];(1,3)  
Because of variations in features such as size and skin colour, different humans belong to different species. [F]
- 61032 The complex languages, technologies, and arts of humans distinguish them (i.e. set them apart) from any other species. [T];(4)  
The complex languages, technologies, and arts of humans do not distinguish them (i.e. set them apart) from any other species. [F]

- 61041 Humans have a much greater *range* of social behaviour than other species. [T];(1,2)  
Humans have about the same *range* of social behaviour as other species. [F]
- 61051 *Over time human practices have changed from hunting-and-gathering to farming.*  
This change was one of the most important events in the history of the human species. [T];(1)  
This change was an unimportant event in the history of the human species. [F]
- 61061 Technology has helped us make up for our biological disadvantages in our day-to-day lives. [T];(3,4)  
Technology has been of little use to us in overcoming our biological disadvantages in our day-to-day lives. [F]

## 6.2. Life cycle

- 62011 A human develops from the fusion (i.e. joining together) of an egg cell and a sperm cell. [T\*];(1)  
A human does not develop from the fusion (i.e. joining together) of an egg cell and a sperm cell. [F]
- 62021 -- [No key idea was found]
- 62031 The death rate of infants varies greatly in various parts of the world. [T];(4)  
The death rate of infants varies little throughout various parts of the world. [F]
- 62032 The death rate of infants depends on factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care. [T];(4)  
The death rate of infants is independent of factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care. [F]
- 62041 The mental development of normal children is characterised by the appearance of abilities (e.g. speech sounds, connected speech) in a particular order. [T];(1)  
The mental development of normal children is characterised by the appearance of abilities (e.g. speech sounds, connected speech) in no particular order. [F]
- 62051 *Compared to other species, humans have an exceptionally long period of development.*  
This long period of human development is related to the important role of the brain in human evolution. [T];(1)  
This long period of human development is unrelated to the important role of the brain in human evolution. [F]
- 62052 For most people the ability to learn lasts throughout life. [T];(5)  
For most people the ability to learn does not last throughout life. [F]
- 62061 *Human developmental stages occur with somewhat different timing for different people.*  
This difference in timing is due to both differing physiological factors and differing experiences in life. [T];(1)  
This difference in timing is unrelated to differing physiological factors and differing experiences in life. [F]
- 62071 Technology has added greatly to the choices which people have in controlling when, and how many, children they have. [T];(2)  
Technology has made no difference to the choices which people have in controlling when, and how many, children they have. [F]
- 62081 Aging is a *normal* process in all humans. [T];(1)  
Aging is an *abnormal* process in all humans. [F]

- 62091 Aging in humans is caused by factors both internal (e.g. changes in the hormonal system) and external (e.g. exposure to harmful substances) to the human body. [T];(1,2,3)  
Aging in humans is only caused by factors internal (e.g. changes in the hormonal system) to the human body. [F]
- 62101 *There appears to be a maximum life span for each species.*  
This includes humans. [T];(1)  
This excludes humans. [F]

### 6.3. Basic functions

- 63011 Organ systems of the human body have specialised functions. [T];(1)  
Organ systems of the human body have unspecialised functions. [F]
- 63021 The immune system plays an important role in the self-protection of humans from disease. [T];(4)  
The immune system plays an unimportant role in the self-protection of humans from disease. [F]
- 63031 *Internal control (i.e. co-ordination) is required for managing and coordinating complex organ systems in the human body.*  
Hormones play an important part in this control. [T];(1)  
Hormones play no part in this control. [F]
- 63041 Reproduction is essential for a species to continue to exist. [T];(1)  
Reproduction is non-essential for a species to continue to exist. [F]

### 6.4. Learning

- 64011 Any new-born animal will show certain patterns of behaviour without having been taught such behaviour. [T];(1)  
Any new-born animal will only show certain patterns of behaviour once it has been taught such behaviour. [F]
- 64021 The behaviour of different people results from the interaction between what they have inherited biologically and differences in the peoples' experiences. [T];(2,3)  
The behaviour of different people is only a function of the characteristics they have inherited. [F]
- 64031 The training of a person's muscles to perform certain tasks occurs mostly through practice. [T];(1)  
The training of a person's muscles to perform certain tasks is only slightly affected by practice. [F]
- 64041 People's senses (e.g. sight, hearing, etc.) do not respond to *all* the stimuli that they receive. [T];(3)  
People's senses (e.g. sight, hearing, etc.) respond to *all* the stimuli that they receive. [F]
- 64051 Much of learning appears to occur by linking a new piece of information with an existing piece of information. [T\*];(1)  
Very little learning appears to occur by linking a new piece of information with an existing piece of information. [F]
- 64061 -- (4) [No meaningful item could be constructed]
- 64071 People's existing ideas can influence learning by affecting how they interpret new facts and ideas. [T];(1)  
People's existing ideas usually do not influence learning even if the ideas affect how people interpret new facts and ideas. [F]

### 6.5. Physical health

- 65011 The human body does not produce *all* chemical substances (e.g. amino acids) that the body needs to operate normally. [T];(3)  
The human body produces *all* chemical substances (e.g. amino acids) that the body needs to operate normally. [F]
- 65012 In order to operate normally, the human body needs substances to replace the materials of which the body is made. [T];(3)  
In order to operate normally, the human body does not need replacement of the materials of which it is made. [F]
- 65021 Good health depends on avoiding being exposed too much to substances that interfere with the body's operation, e.g. tobacco and alcohol. [T];(1,2)  
The human body can cope with too much exposure to substances that interfere with the body's operation, and *still* maintain good health. [F\*]
- 65022 The good health of individuals depends on people's collective effort to take steps to keep their air, soil, and water safe. [T];(4)  
The good health of individuals is independent of people's collective effort to take steps to keep their air, soil, and water safe. [F]
- 65031 Viruses can interfere with the human body's normal operation. [T];(1,2,3,4)  
Viruses do not interfere with the human body's normal operation. [F]
- 65041 The human body's *own* first line of defense against disease-causing organisms is to keep these organisms from entering the body. [T];(1)  
The human body's *own* first line of defense against disease-causing organisms only comes into play once these organisms have entered and settled in the body. [F]
- 65051 The immune system is the human body's own *second* line of defense against disease-causing organisms. [T];(1)  
The human body's own *first* line of defense against disease-causing organisms is the immune system. [F]
- 65061 Abnormal genes may cause human body parts or systems to function poorly. [T];(2,3)  
Abnormal genes do not affect how human body parts or systems function. [F]
- 65071 *The societal and physical conditions in which people live now are very different from those to which the human body was adapted long ago.*  
This change in the general living environment is a factor in determining the health of the general population. [T];(1)  
This change in the general living environment has nothing to do with determining the health of the general population. [F]

### 6.6. Mental health

- 66011 Good mental health involves the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life. [T];(1)  
Good mental health is unrelated to the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life. [F]
- 66012 In different cultures people have different ideas about what is good mental health. [T];(3)  
Ideas about what is good mental health are the same in different cultures. [F]

- 66013 In different time periods (i.e. at different times in history) people have different ideas about what is good mental health. [T]; (3)  
Ideas about what is good mental health are the same in different time periods (i.e. at different times in history).
- 66021 Not all people are able to cope the same with stressful environments. [T];(1)  
All people are able to cope the same with stressful environments. [F]
- 66031 *The diagnosis and treatment of mental disturbances can be particularly difficult.*  
This is because most people do not understand everything that goes on in their minds. [T];(1)  
This is because most people usually understand everything that goes on in their minds. [F]
- 66041 Biological abnormalities (such as a chemical imbalance in the brain) cause some kinds of severe psychological disturbance. [T];(1)  
Biological abnormalities (such as a chemical imbalance in the brain) cause no psychological disturbance. [F]
- 66051 Psychological distress (such as the death of a close family member) may increase any person's chance of becoming physically ill. [T];(3)  
Psychological distress (such as the death of a close family member) does not affect any person's chance of becoming physically ill. [F]



## **Appendix D**

### **PILOT TEST-FORMS**





**APPENDIX D1**

**U N I V E R S I T Y   O F   C A P E   T O W N**

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**S C I E N C E   Q U E S T I O N N A I R E**

*Form PT-a*

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Science Education Unit, School of Education, University of Cape Town,  
Rondebosch 7700

## ABOUT THIS QUESTIONNAIRE

We are interested in finding out what you know about the Sciences in general. We know, that some of you will not have taken any science subjects in Matric, but please do not worry! **We are simply interested in what you know *now*, regardless of your matric subjects.** Therefore do not be afraid to answer "I don't know"!

This questionnaire is divided into two sections. In Section A, you are asked a number of questions about yourself and about your matric. In Section B, you are asked to decide whether statements are true or false or whether you do not know the answer.

*Your answers will remain totally confidential and will not be associated with your identity at any stage.*

We begin, then, with Section A.

Form PT

a

1-5

## SECTION A

1. Is this your very first year of registration at any Technikon or University? (Please tick the appropriate box)

Yes

No

2. Where are you presently studying? (Please tick the appropriate box)

Cape Technikon

☐

1

University of Cape Town

☐

2

6

3. In which School (Cape Technikon students) or Faculty (UCT students) are you currently registered? (Please tick the appropriate box)

**School**

Electrical Engineering

☐

11

Business Management

☐

12

Other (please specify):

☐

13

**Faculty**

Arts

☐

21

Science

☐

22

Social Sciences &amp; Humanities

☐

23

Other (please specify):

☐

24

7-8

4. How old will you turn this year?

years

9-10

5. Are you Male or Female? (Please tick the appropriate box)

M

1

F

2

11

6. What is your home language? (Please tick the appropriate box)

Afrikaans

☐

01

English

☐

02

Ndebele

☐

03

Northern Sotho

☐

04

Southern Sotho

☐

05

Swazi

☐

06

Tsonga

☐

07

Tswana

☐

08

Venda

☐

09

Xhosa

☐

10

Zulu

☐

11

Other (please specify):

☐

12

12-13

7. In which year did you pass your Matric?

19

8. Through which Education Authority did you complete your Matric? (Please tick the appropriate box)

Cape Education Department (CED)	<input type="checkbox"/>	01
Department of Education and Training (DET)	<input type="checkbox"/>	02
Department of Education and Culture - House of Delegates (DEC)	<input type="checkbox"/>	03
Department of Education and Culture - House of Representatives (DEC)	<input type="checkbox"/>	04
Joint Matriculation Board (JMB)	<input type="checkbox"/>	05
Natal Education Department (NED)	<input type="checkbox"/>	06
Orange Free State Education Department	<input type="checkbox"/>	07
Transkei Education Department	<input type="checkbox"/>	08
Transvaal Education Department (TED)	<input type="checkbox"/>	09
Other (please specify): _____	<input type="checkbox"/>	10

9. Which Science subjects did you take up to Matric? At Higher (HG) or Standard (SG) Grade?  
What symbol did you receive for each of them? (Please tick the appropriate box or boxes)

Subject		Grade		Symbol	
None	<input type="checkbox"/> 1	Not Applicable		Not Applicable	18-
Agricultural Sciences	<input type="checkbox"/> 2	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	21-
Biology	<input type="checkbox"/> 3	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	24-
Geography	<input type="checkbox"/> 4	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	27-
Physical Science	<input type="checkbox"/> 5	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	30-
Physiology	<input type="checkbox"/> 6	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	33-
Other (please specify): _____	<input type="checkbox"/> 7	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	36-

So far, so good! This is the end of Section A. Now please turn the page to start Section B.

## SECTION B

The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T) or FALSE (F), or whether you really DON'T KNOW (?) the answer. *Please tick the appropriate box.*

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. **Please take this sentence to be TRUE!** The statement to which you must respond refers to this true sentence.

**Please work swiftly and carefully, and try to answer *all* the questions.**

- |     |   |                            |                            |                            |    |
|-----|---|----------------------------|----------------------------|----------------------------|----|
| 10. | The earth is only about a third as old as the universe.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 39 |
| 11. | Our galaxy only contains a few thousand stars.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 40 |
| 12. | Light from the star nearest to our sun takes only a few minutes to reach us.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 41 |
| 13. | All other galaxies are similar in size and shape to our own galaxy.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 42 |
| 14. | In other galaxies, there appear to be the same elements, forces, and forms of energy as are found in our own galaxy.                          | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 43 |
| 15. | It seems that the entire known universe came into existence more than 10 thousand million years ago.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 44 |
| 16. | Everything in and on the earth is made of material that has originated from a giant cloud of gas and dust.                                    | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 45 |
| 17. | All planets move around our sun.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 46 |
| 18. | We know everything that there is to know about the solar system and the rest of the universe.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 47 |
| 19. | Most of our knowledge of the universe comes from looking at the universe as a whole.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 48 |
| 20. | The shape of the earth is almost spherical.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 49 |
| 21. | Compared to the earth's diameter, a thin blanket of air surrounds the entire earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 50 |
| 22. | There is liquid water at the surface of planets other than the earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 51 |
| 23. | The stars rotate (i.e. turn) around the stationary earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 52 |
| 24. | <i>The earth's axis is tilted, i.e. slanted.</i> This tilt produces seasonal changes in the earth's climate.                                  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 53 |
| 25. | <i>Water continuously moves in and out of the atmosphere.</i> This plays an extremely small role in determining patterns in climate on earth. | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 54 |
| 26. | The earth's climate is expected to remain the same over thousands of years.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 55 |

27.	Fresh water is a non-essential resource for daily life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	56
28.	The oceans and atmosphere can only be changed by a limited amount before affecting human activities unfavourably.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	57
29.	<i>The earth's minerals (e.g. quartz, asbestos, copper) are formed, dissolved, and reformed.</i> These processes take place on the earth's surface, in the oceans, and in the layers beneath the earth's crust.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	58
30.	<i>Elements such as carbon, oxygen, nitrogen, and sulphur, move slowly through the land, oceans, and atmosphere.</i> While doing so, elements do <u>not</u> change their chemical combinations.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	59
31.	The landforms (e.g. mountains, valleys, etc.), climate, and resources of the earth's surface have little affect on where and how people live.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	60
32.	Scientists do <u>not</u> share beliefs and attitudes about what they do and how they view their work.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	61
33.	Science takes for granted that patterns in the universe are hardly ever understood through careful study.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	62
34.	In science, the testing, improving and discarding of theories goes on all the time.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	63
35.	Scientists believe that most scientific knowledge does <u>not</u> last a long time but is ever-changing.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	64
36.	There are many aspects of our lives that <u>cannot</u> be usefully examined in a scientific way.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	65
37.	There are <u>no</u> fixed steps that scientists always follow to lead them without fail to scientific knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	66
38.	The validity (i.e. truth) of scientific claims is seldom settled by referring to observations of phenomena.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	67
39.	Scientists disagree about the principles of logical reasoning that connect evidence with conclusions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	68
40.	Science is as creative as writing poetry or composing music.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	69
41.	Scientific theories should explain <b>additional</b> observations that were <u>not</u> used in developing the theories in the first place.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	70
42.	In spite of their background, personal beliefs and values, scientists do <u>not</u> look for different types of evidence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	71
43.	Scientists do <u>not</u> try to identify possible bias in the work of other scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	72
44.	In carrying out an investigation, a scientist is often made to feel that s/he should reach a particular result.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	73
45.	Scientific activity is one of the main features of the world today.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	74

46.	Even though science is an activity carried out by many different people, science hardly ever reflects values and viewpoints related to society (e.g. views on women, political beliefs).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	75
47.	Science only takes place in universities and technikons, and <u>not</u> in either business, industry, classrooms, the outdoors, etc.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	76
48.	<i>Scientific fields such as archaeology and zoology differ from one another in many ways.</i> In spite of this difference, they are all equally scientific with respect to purpose and philosophy.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	77
49.	The bodies (e.g. the different government departments) which supply money for scientific research seldom influence the direction of science (i.e. which research to undertake).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	78
50.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harm that could result from scientific experiments.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	79
51.	Scientists can often play an important advisory role in matters of public interest (e.g. nuclear power or conservation of the environment).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	80
52.	In many public matters, scientists can be expected to be biased where their own interests are at stake (e.g. building a new highway near their home).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	81
53.	<i>Biologists classify organisms into groups and subgroups.</i> This is done on the basis of the structure and behaviour of the organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	82
54.	Biological classification systems are <u>not</u> created by biologists but are part of nature.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	83
55.	<i>In living organisms, most complex molecules are made up of chains of smaller molecules.</i> In each species, there are <u>no</u> characteristic sequences of small molecules that make up complex molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	84
56.	In obtaining the energy and materials necessary for life, human beings are independent of food webs (i.e. interlinked food chains).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	85
57.	Offspring (i.e. young) always differ in some respects from their parents.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	86
58.	In humans, instructions for development from egg to adult are passed from parents to offspring (i.e. young) in many thousands of genes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	87
59.	The "mixing" of genes in sexual reproduction results in a great variety of gene combinations among the offspring (i.e. young) of two parents.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	88
60.	The "information" in a cell's DNA always remains the same.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	89
61.	The genetic information encoded in DNA molecules provides instructions for assembling protein molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	90
62.	The chemical processes in the cell are controlled from inside the cell only.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	91
63.	In an ecosystem, every species depends, directly or indirectly, on all other species in that system.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	92
64.	To understand any one part of an ecosystem, we need to know how that part of the ecosystem interacts with the other parts of the ecosystem.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	93



65.	Ecosystems tend to show random fluctuations around a state of near equilibrium.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	94
66.	Ecosystems cannot avoid changing when very different new species appear.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	95
67.	Only a small proportion of life on earth is basically maintained by transformations of energy from the sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	96
68.	Coal and oil were formed thousands of years ago.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	97
69.	<i>Carbon dioxide was removed from the atmosphere over millions of years.</i> By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at a much faster rate than the rate at which carbon dioxide was removed from the atmosphere.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	98
70.	The earth's present-day life-forms have evolved from common ancestors over many millions of years.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	99
71.	<i>The fossil record stretches back over millions of years.</i> Since the beginning of the fossil record, most old life-forms, such as species, have remained in existence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	100
72.	The result of natural selection is that over successive generations within any species, the proportion of individuals that have inherited advantage-giving characteristics will tend to increase.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	101
73.	New combinations or mutations of parents' genes do <u>not</u> result in new characteristics which can be inherited.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	102
74.	Natural selection always results in increasingly greater advantages of an organism's characteristics.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	103
75.	Evolution is a ladder with humans finally emerging at the top as the most advanced species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	104
76.	Scientific understanding is just as important to technology as accumulated practical knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	105
77.	New instruments and techniques being developed through technology make little contribution to scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	106
78.	As technology becomes more sophisticated (i.e. advanced), technology's links to science becomes stronger.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	107
79.	New scientific investigations seldom need new technology.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	108
80.	Many scientists and engineers do work that could be described as engineering as well as science.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	109
81.	In the short term, engineering affects societies and cultures more directly than scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	110
82.	Every engineering design operates within constraints (e.g. physical laws, economics, politics) that must be identified and taken into account.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	111

83.	<i>Different people place different values on different constraints (e.g. physical laws, economics, politics) that act on engineering designs (e.g. a person may favour a safer but more expensive design). Because of this difference in people's values, every engineering design problem has many alternative solutions.</i>	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	112
84.	Engineering designs almost always need to be tested.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	113
85.	The ultimate control of technological systems lies with mechanical and electronic devices rather than with people who understand the control process and the context in which the control process operates.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	114
86.	In spite of the great complexity of modern technological systems, all side effects of new technological designs are predictable (i.e. can be forecast).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	115
87.	A technological system is usually designed so that its most likely way of failing will do the least harm.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	116
88.	Social and economic forces within a country strongly influence what technologies will be developed within that country.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	117
89.	Technology has had little influence on the nature of human society.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	118
90.	Factors such as potential economic value or potential military applications may restrict (i.e. limit) the free flow of technological or scientific knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	119
91.	The relevant technical facts alone usually settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the proposal.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	120
92.	Most decisions on technology-related issues are made using complete information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	121
93.	<u>Not</u> all things of the physical world are made up of different combinations of about 100 chemical elements.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	122
94.	At extremely high temperatures nuclei of atoms may join together (i.e. fuse).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	123
95.	A low level of background radiation exists naturally in the general environment (i.e. the world around us).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	124
96.	In the universe, energy appears only in one particular form.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	125
97.	Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by a larger amount.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	126
98.	When atoms or molecules interact, they will usually end up in less order than they began with.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	127
99.	Arrangements of atoms in molecules are unrelated to different energy levels of the molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	128
100.	Reactions in the nuclei of atoms involve far greater energy changes than those between the outer electrons of atoms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	129
101.	All motion is relative to whatever point or object we choose.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	130

102.	The observed wavelength of a wave depends in part upon the relative motion of the source of the wave with respect to the observer.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	133
103.	Materials that allow one range of wavelengths of electromagnetic radiation (e.g. visible light, ultraviolet light, X-rays) to pass through them may completely absorb other ranges.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	134
104.	Every object in the universe exerts gravitational forces on nearby objects only.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	135
105.	How materials conduct electricity depends on how many of the electric charges in them are free to move.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	136
106.	A changing electric field does <u>not</u> produce a magnetic field.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	137
107.	In most biological respects, humans are unlike other living organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	138
108.	Because of variations in features such as size and skin colour, different humans belong to different species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	139
109.	Humans have a much greater range of social behaviour than other species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	140
110.	Technology has been of little use to us in overcoming our biological disadvantages in our day-to-day lives.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	141
111.	The death rate of infants varies greatly in various parts of the world.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	142
112.	The mental development of normal children is characterised by the appearance of abilities (e.g. speech sounds, connected speech) in a particular order.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	143
113.	For most people the ability to learn does <u>not</u> last throughout life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	144
114.	Technology has made no difference to the choices which people have in controlling when, and how many, children they have.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	145
115.	Aging in humans is only caused by factors internal to the human body (e.g. changes in the hormonal system).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	146
116.	Organ systems of the human body have unspecialised functions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	147
117.	<i>Internal control (i.e. co-ordination) is required for managing complex organ systems in the human body.</i> Hormones play an important part in this control.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	148
118.	Any new-born animal will show certain patterns of behaviour without having been taught such behaviour.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	149
119.	The training of a person's muscles to perform certain tasks occurs mostly through practice.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	150
120.	Much of learning appears to occur by linking a new piece of information with an existing piece of information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	151
121.	The human body produces all chemical substances (e.g. amino acids) that the body needs to operate normally.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	152

- |      |   |                            |                            |                            |     |
|------|---|----------------------------|----------------------------|----------------------------|-----|
| 122. | The human body can cope with too much exposure to substances that interfere with the body's operation, and still maintain good health.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 151 |
| 123. | Viruses do <u>not</u> interfere with the human body's normal operation.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 152 |
| 124. | The human body's own first line of defense against disease-causing organisms is the immune system.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 153 |
| 125. | <i>The societal and physical conditions in which people live now are very different from those to which the human body was adapted long ago. This change in the general living environment has nothing to do with determining the health of the general population.</i> | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 154 |
| 126. | Ideas about what is good mental health are the same in different cultures.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 155 |
| 127. | Not all people are able to cope the same with stressful environments.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 156 |
| 128. | Biological abnormalities (such as a chemical imbalance in the brain) cause some kinds of severe psychological disturbance.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 157 |

You have reached the end of the questionnaire.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!



**APPENDIX D2**

**U N I V E R S I T Y   O F   C A P E   T O W N**

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**S C I E N C E   ·   Q U E S T I O N N A I R E**

*Form PT-b*

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Science Education Unit, School of Education, University of Cape Town,  
Rondebosch 7700

## ABOUT THIS QUESTIONNAIRE

We are interested in finding out what you know about the Sciences in general. We know, that some of you will not have taken any science subjects in Matric, but please do not worry! **We are simply interested in what you know *now*, regardless of your matric subjects.** Therefore do not be afraid to answer "I don't know"!

This questionnaire is divided into two sections. In Section A, you are asked a number of questions about yourself and about your matric. In Section B, you are asked to decide whether statements are true or false or whether you do not know the answer.

*Your answers will remain totally confidential and will not be associated with your identity at any stage.*

We begin, then, with Section A.

Form PT

b

1-5

## SECTION A

1. Is this your very first year of registration at any Technikon or University? (Please tick the appropriate box)

Yes

No

2. Where are you presently studying? (Please tick the appropriate box)

Cape Technikon

☐

1

University of Cape Town

☐

2

6

3. In which School (Cape Technikon students) or Faculty (UCT students) are you currently registered? (Please tick the appropriate box)

**School**

Electrical Engineering

☐

11

Business Management

☐

12

Other (please specify):

☐

13

**Faculty**

Arts

☐

21

Science

☐

22

Social Sciences &amp; Humanities

☐

23

Other (please specify):

☐

24

7-8

4. How old will you turn this year?

years

9-10

5. Are you Male or Female? (Please tick the appropriate box)

M

1

F

2

11

6. What is your home language? (Please tick the appropriate box)

Afrikaans

☐

01

English

☐

02

Ndebele

☐

03

Northern Sotho

☐

04

Southern Sotho

☐

05

Swazi

☐

06

Tsonga

☐

07

Tswana

☐

08

Venda

☐

09

Xhosa

☐

10

Zulu

☐

11

Other (please specify):

☐

12

12-13



7. In which year did you pass your Matric?

19

14-

8. Through which Education Authority did you complete your Matric? *(Please tick the appropriate box)*

Cape Education Department (CED)	<input type="checkbox"/>	01
Department of Education and Training (DET)	<input type="checkbox"/>	02
Department of Education and Culture - House of Delegates (DEC)	<input type="checkbox"/>	03
Department of Education and Culture - House of Representatives (DEC)	<input type="checkbox"/>	04
Joint Matriculation Board (JMB)	<input type="checkbox"/>	05
Natal Education Department (NED)	<input type="checkbox"/>	06
Orange Free State Education Department	<input type="checkbox"/>	07
Transkei Education Department	<input type="checkbox"/>	08
Transvaal Education Department (TED)	<input type="checkbox"/>	09
Other (please specify): _____	<input type="checkbox"/>	10

16-

9. Which Science subjects did you take up to Matric? At Higher (HG) or Standard (SG) Grade?  
What symbol did you receive for each of them? *(Please tick the appropriate box or boxes)*

Subject		Grade		Symbol	
None	<input type="checkbox"/> 1	Not Applicable		Not Applicable	18-
Agricultural Sciences	<input type="checkbox"/> 2	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	21-
Biology	<input type="checkbox"/> 3	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	24-
Geography	<input type="checkbox"/> 4	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	27-
Physical Science	<input type="checkbox"/> 5	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	30-
Physiology	<input type="checkbox"/> 6	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	33-
Other (please specify): _____	<input type="checkbox"/> 7	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	36-

## SECTION B

The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T) or FALSE (F), or whether you really DON'T KNOW (?) the answer. *Please tick the appropriate box.*

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. **Please take this sentence to be TRUE!** The statement to which you must respond refers to this true sentence.

**Please work swiftly and carefully, and try to answer *all* the questions.**

10.	Our sun is a planet.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	39
11.	Apart from our own, there are no other galaxies in the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	40
12.	In the universe there are no other bodies similar to our sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	41
13.	It seems that the known universe has always existed in much the same form as it is today.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	42
14.	Our solar system came into existence about 5 thousand million years ago.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	43
15.	There are nine major planets in our solar system.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	44
16.	Apart from the planets, there are a great many small objects of rock and ice moving around our sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	45
17.	Our knowledge of the universe comes to us mostly by direct observation with the naked eye.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	
18.	We live in one of many known systems of planets.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	47
19.	About three-quarters of the earth's surface is covered by a layer of water.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	48
20.	Of all the planets and moons in our solar system, only the earth appears able to support life as we know it.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	49
21.	The earth orbits (i.e. moves around) the sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	50
22.	The earth orbits (i.e. moves around) the moon.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	51
23.	Varying radiation from the sun is the basic cause of changes in climate on earth.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	52
24.	The earth's climate has changed totally over thousands of years.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	53
25.	<i>The earth has many resources of great importance to human life. All these resources can be equally renewed.</i>	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	54
26.	Fresh water is a non-essential resource for industrial processes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	55

27.	Forces within the earth do <u>not</u> affect its surface.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	56
28.	Only wind changes the earth's surface to produce distinctive landforms (e.g. mountains, valleys, etc.).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	57
29.	The presence of life has altered the earth's atmosphere.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	58
30.	Human activities have changed the earth's land surface, oceans, and atmosphere.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	59
31.	Science takes for granted that the things and events in the universe occur in consistent patterns.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	60
32.	Science assumes that the rules about how the universe operates may <u>not</u> be the same throughout the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	61
33.	Scientists reject the idea that we will one day know everything there is to know about the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	62
34.	Normally in science ideas are modified (i.e. changed) rather than rejected outright.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	63
35.	Scientists working in different scientific fields agree about what makes a scientific investigation valid.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	64
36.	Science does <u>not</u> have a distinctive (i.e. special) character as a way of enquiry.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	65
37.	In science, the findings of any one investigator or group are usually checked by other scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	66
38.	The process of putting forward and testing hypotheses (i.e. provisional explanations) is <u>not</u> one of the chief activities of scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	67
39.	<i>Scientists try to make sense of phenomena by inventing explanations for them.</i> These explanations rarely use currently accepted scientific principles.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	68
40.	Scientific evidence is never biased (i.e. distorted) in the way that data are selected, recorded, interpreted or reported.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	69
41.	In spite of their background, personal beliefs and values, scientists do <u>not</u> emphasise different interpretations of evidence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	70
42.	Scientists are <u>not</u> usually expected to safeguard against possible bias in their own work.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	71
43.	Challenges to new ideas are an important part of science in building valid (i.e. truthful) knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	72
44.	Scientific work (i.e. research and teaching) goes on in only a few nations of the world.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	73
45.	The direction of scientific research (e.g. which questions are considered worth asking) is affected by influences within science itself.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	74
46.	The spreading of scientific information is crucial to the progress of science.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	75

47.	Scientific fields such as chemistry and biology have fixed boundaries or borders.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	76
48.	There are few traditions in science that result in most scientists behaving professionally and ethically (i.e. in a moral and honest way).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	77
49.	Scientific ethics (i.e. system of morals) is <u>not</u> concerned with the possible harmful effects of applying the results of research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	78
50.	Scientists can seldom bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	79
51.	When scientists classify organisms, they consider behaviour and appearance to be just as important as anatomy (i.e. structure).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	80
52.	Biological classification systems suggest relationships among living things.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	81
53.	Keeping a great variety of species on earth is important to human beings.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	82
54.	Maintaining relatively large populations of a great variety of species increases the chance that some individuals of some species will be able to survive under changed conditions, e.g. climate.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	83
55.	Offspring (i.e. young) are always identical to one another.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	84
56.	Each gene is one - or more than one - particular segment of a molecule of protein.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	85
57.	New "mixes" of genes as a result of sexual reproduction are <u>not</u> the only source of variation in the characteristics of organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	86
58.	All life-forms on earth are made up of cells.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	87
59.	The function or work of the cell is carried out mostly by different types of protein molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	88
60.	<i>Most organisms have many different cells.</i> In such organisms, most cells perform some special functions that other cells do <u>not</u> .	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	89
61.	In an ecosystem, life-forms interact with one another and with the environment.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	90
62.	The interdependence of organisms in an ecosystem results in very little stability of the system over a very long time.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	91
63.	Ecosystems cannot avoid changing when the climate changes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	92
64.	Living organisms share with all other natural systems the same principles of the conservation of matter and energy.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	93
65.	The elements that make up the molecules of living things are continuously recycled.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	94
66.	Coal and oil were formed from organic material.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	95

67.	The amount of life any environment can support is unlimited.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	96
68.	<i>The fossil record stretches back over millions of years.</i> Since the beginning of the fossil record, huge numbers of new life-forms, such as species, have appeared.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	97
69.	Life on earth has existed for only a few thousand years.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	98
70.	Natural selection can act upon biochemistry, anatomical features and behaviour.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	99
71.	Natural selection is likely to lead to organisms with characteristics that are well adapted to survival in particular environments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100
72.	Evolution is <u>not</u> a ladder in which the lower life-forms are all replaced with superior forms.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	101
73.	The modern concept of evolution does <u>not</u> provide a unifying principle for understanding the history of life on earth.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	102
74.	<i>Engineers use technology together with design strategies (i.e. ways of designing) to solve practical problems.</i> Knowledge of science is seldom used in this process of solving practical problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	103
75.	Technology does not just provide tools for science - it may also provide motivation and direction for theory and research in science.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	104
76.	New technology often needs new scientific understanding.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	105
77.	Engineers can design solutions for all our problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	106
78.	<i>Decisions in engineering inevitably (i.e. without fail) involve scientific judgements.</i> These decisions exclude social and personal values.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	107
79.	<i>In engineering, a design takes into account all the constraints (e.g. physical laws, economics, politics).</i> An optimum (i.e. "best") design allows no compromise (i.e. balance) among the different constraints.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	108
80.	It is not practical for engineers to design something (be it a machine or a chemical process) without considering where and how it will be used.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	109
81.	Few engineering systems need control to keep them operating properly, i.e. comparing information about what is happening with what we want to happen, and then making appropriate adjustments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	110
82.	In addition to its intended benefits, every engineering design is likely to have unintended side effects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	111
83.	<i>The effects of large numbers of relatively simple objects (e.g. refrigerators or solar cookers) may be individually small.</i> However, these effects may be collectively significant.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	112
84.	People's psychological reactions to risk (e.g. their fear of flying or driving) match the reality of the risks involved.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	113

85.	If sufficient precautions are taken or enough money is spent, a technological system can be designed so that it <u>cannot</u> fail.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	114
86.	Technology has strongly influenced the course of history.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	115
87.	Technological and social change have little influence on each other.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	116
88.	The total effect of decisions by large numbers of individuals <u>cannot</u> influence the large-scale use of technology as much as pressure on government decisions can.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	117
89.	Technology-related decisions are unlikely to be influenced as much by politics as by technical factors.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	118
90.	There is only one kind of atom for each of the chemical elements.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	119
91.	The number of different states (i.e. solid, liquid, or gas) that every substance can exist in has nothing to do with temperature and pressure.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	120
92.	The way atoms bond together is determined by the arrangement of <i>all</i> the electrons in each atom.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	
93.	<i>Radioactive nuclei are unstable and eventually break up.</i> One <u>cannot</u> predict when a particular unstable nucleus will break up.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	122
94.	Very little of what happens in the universe involves one form of energy being changed into another form.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	123
95.	The total amount of useful energy in a system, such as an electric hot-water tank, is decreasing unless it is continuously supplied with electricity.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	124
96.	The <u>total</u> amount of order in the matter making up the universe is increasing.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	125
97.	Energy as well as matter occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	126
98.	Most things in the universe - whether atoms, living things, or stars - are at rest, and are <u>not</u> moving relative to something else.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	127
99.	Unbalanced forces play <u>no</u> role in changes in motion.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	128
100.	The interaction between waves and matter can be greatly influenced by the wavelength of the wave.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	129
101.	The <u>electromagnetic</u> forces acting between atoms are about as strong as the <u>gravitational</u> forces acting between them.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	130
102.	Magnetic forces are very closely related to electric forces.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	131
103.	Some forces operate only inside the nucleus of an atom.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	132
104.	There is much evidence that the human species evolved from other organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	133

105.	The complex languages, technologies, and arts of humans do <u>not</u> distinguish them (i.e. set them apart) from any other species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	134
106.	<i>Over time human practices have changed from hunting-and-gathering to farming.</i> This change was one of the most important events in the history of the human species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	135
107.	A human develops from the fusion (i.e. joining together) of an egg cell and a sperm cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	136
108.	The death rate of infants depends on factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	137
109.	<i>Compared to other species, humans have an exceptionally long period of development.</i> This long period of human development is unrelated to the important role of the brain in human evolution.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	138
110.	<i>Human developmental stages occur with somewhat different timing for different people.</i> This difference in timing is due to both differing physiological factors and to people's differing experiences in life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	139
111.	Aging is a normal process in all humans.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	140
112.	<i>There appears to be a maximum life span for each species.</i> This excludes humans.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	141
113.	The immune system plays an unimportant role in the self-protection of humans from disease.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	142
114.	Reproduction is non-essential for a species to continue to exist.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	143
115.	The behaviour of different people is only a function what they have inherited biologically and is unrelated to differences in the people's experiences.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	144
116.	People's senses (e.g. sight, hearing, etc.) do <u>not</u> respond to all the stimuli that they receive.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	145
117.	People's existing ideas can influence learning by affecting how they interpret new facts and ideas.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	146
118.	In order to operate normally, the human body needs substances to replace the materials of which the body is made.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	147
119.	The good health of individuals depends on people's collective effort to take steps to keep their air, soil, and water safe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	148
120.	The human body's <u>own</u> first line of defense against disease-causing organisms only comes into play once these organisms have entered and settled in the body.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	149
121.	Abnormal genes may cause human body parts or systems to function poorly.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	150
122.	Good mental health involves the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	151
123.	Ideas about what is good mental health are the same at different times in history.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	152

- |      |   |                            |                            |                            |     |
|------|---|----------------------------|----------------------------|----------------------------|-----|
| 124. | <i>The diagnosis and treatment of mental disturbances can be particularly difficult.</i> This is because most people do <u>not</u> understand everything that goes on in their minds. | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 153 |
| 125. | Psychological distress (such as the death of a close family member) may increase any person's chance of becoming physically ill.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 154 |
| 126. | On the earth's surface, vibrations set up a travelling disturbance that spreads away from its source.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 155 |

You have reached the end of the questionnaire.

**THANK YOU VERY MUCH FOR YOUR PARTICIPATION!**





U N I V E R S I T Y   O F   C A P E   T O W N

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**S C I E N C E   Q U E S T I O N N A I R E**

*Form PT-c*

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Science Education Unit, School of Education, University of Cape Town,  
Rondebosch 7700

## ABOUT THIS QUESTIONNAIRE

We are interested in finding out what you know about the Sciences in general. We know, that some of you will not have taken any science subjects in Matric, but please do not worry! **We are simply interested in what you know *now*, regardless of your matric subjects.** Therefore do not be afraid to answer "I don't know"!

This questionnaire is divided into two sections. In Section A, you are asked a number of questions about yourself and about your matric. In Section B, you are asked to decide whether statements are true or false or whether you do not know the answer.

*Your answers will remain totally confidential and will not be associated with your identity at any stage.*

We begin, then, with Section A.

Form PT

c

1-5

## SECTION A

1. Is this your very first year of registration at any Technikon or University? (Please tick the appropriate box)

Yes

No

2. Where are you presently studying? (Please tick the appropriate box)

Cape Technikon

☐

1

University of Cape Town

☐

2

6

3. In which School (Cape Technikon students) or Faculty (UCT students) are you currently registered? (Please tick the appropriate box)

**School**

Electrical Engineering

☐

11

Business Management

☐

12

Other (please specify):

☐

13

**Faculty**

Arts

☐

21

Science

☐

22

Social Sciences &amp; Humanities

☐

23

Other (please specify):

☐

24

7-8

4. How old will you turn this year?

years

9-10

5. Are you Male or Female? (Please tick the appropriate box)

M

1

F

2

11

6. What is your home language? (Please tick the appropriate box)

Afrikaans

☐

01

English

☐

02

Ndebele

☐

03

Northern Sotho

☐

04

Southern Sotho

☐

05

Swazi

☐

06

Tsonga

☐

07

Tswana

☐

08

Venda

☐

09

Xhosa

☐

10

Zulu

☐

11

Other (please specify):

☐

12

12-13

7. In which year did you pass your Matric?

19

14-1

8. Through which Education Authority did you complete your Matric? *(Please tick the appropriate box)*

Cape Education Department (CED)	<input type="checkbox"/>	01
Department of Education and Training (DET)	<input type="checkbox"/>	02
Department of Education and Culture - House of Delegates (DEC)	<input type="checkbox"/>	03
Department of Education and Culture - House of Representatives (DEC)	<input type="checkbox"/>	04
Joint Matriculation Board (JMB)	<input type="checkbox"/>	05
Natal Education Department (NED)	<input type="checkbox"/>	06
Orange Free State Education Department	<input type="checkbox"/>	07
Transkei Education Department	<input type="checkbox"/>	08
Transvaal Education Department (TED)	<input type="checkbox"/>	09
Other (please specify): _____	<input type="checkbox"/>	10

16-1

9. Which Science subjects did you take up to Matric? At Higher (HG) or Standard (SG) Grade?  
What symbol did you receive for each of them? *(Please tick the appropriate box or boxes)*

Subject		Grade		Symbol	
None	<input type="checkbox"/> 1	Not Applicable		Not Applicable	18-2
Agricultural Sciences	<input type="checkbox"/> 2	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	21-2
Biology	<input type="checkbox"/> 3	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	24-2
Geography	<input type="checkbox"/> 4	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	27-2
Physical Science	<input type="checkbox"/> 5	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	30-3
Physiology	<input type="checkbox"/> 6	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	33-3
Other (please specify): _____	<input type="checkbox"/> 7	<input type="checkbox"/> HG 1	<input type="checkbox"/> SG 2	<input type="checkbox"/>	36-3

So far, so good! This is the end of Section A. Now please turn the page to start Section B.

## SECTION B

The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T) or FALSE (F), or whether you really DON'T KNOW (?) the answer. *Please tick the appropriate box.*

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. **Please take this sentence to be TRUE!** The statement to which you must respond refers to this true sentence.

**Please work swiftly and carefully, and try to answer *all* the questions.**

- |     |   |                            |                            |                            |    |
|-----|---|----------------------------|----------------------------|----------------------------|----|
| 10. | The earth is as old as the universe.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 39 |
| 11. | Our galaxy contains many thousands of millions of stars.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 40 |
| 12. | Light from the star nearest to our sun takes about four years to reach us.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 41 |
| 13. | There are other galaxies different in size and shape from our own galaxy.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 42 |
| 14. | In other galaxies, there appear to be different elements, forces, and forms of energy as are found in our own galaxy.                   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 43 |
| 15. | It seems that the entire known universe came into existence no more than a few thousand years ago.                                      | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 44 |
| 16. | Everything in and on the earth is made of material that has <u>not</u> originated from a giant cloud of gas and dust.                   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 45 |
| 17. | Only a <b>few</b> of the planets move around our sun.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 46 |
| 18. | Our knowledge of the solar system and the rest of the universe is still growing.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 47 |
| 19. | Most of our knowledge of the universe comes from looking at very small slices of space and small intervals of time.                     | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 48 |
| 20. | Compared to the earth's diameter, a very thick blanket of air surrounds the entire earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 49 |
| 21. | There is no liquid water at the surface of planets other than the earth.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 50 |
| 22. | The earth rotates (i.e. turns) on its axis.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 51 |
| 23. | <i>The earth's axis is tilted, i.e. slanted.</i> This tilt has nothing to do with seasonal changes in the earth's climate.              | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 52 |
| 24. | <i>Water continuously moves in and out of the atmosphere.</i> This plays an important role in determining patterns in climate on earth. | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 53 |
| 25. | The earth's climate is expected to change over thousands of years.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 54 |
| 26. | Fresh water is an essential resource for daily life.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 55 |

27.	The oceans and atmosphere can be changed by an unlimited amount without affecting human activities unfavourably.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	56
28.	<i>The earth's minerals (e.g. quartz, asbestos, copper) are formed, dissolved, and reformed.</i> These processes take place only in the layers beneath the earth's crust.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	57
29.	<i>Elements such as carbon, oxygen, nitrogen, and sulphur, move slowly through the land, oceans, and atmosphere.</i> While doing so, elements change their chemical combinations.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	58
30.	The landforms (e.g. mountains, valleys, etc.), climate, and resources of the earth's surface affect where and how people live.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	59
31.	Scientists share certain beliefs and attitudes about what they do and how they view their work.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	60
32.	Science takes for granted that patterns in the universe may be understood through careful study.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	61
33.	In science, the testing, improving and discarding of theories takes place only rarely.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	62
34.	Scientists believe that most scientific knowledge is durable (i.e. lasts a long time).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	63
35.	Any aspect of our lives can be usefully examined in a scientific way.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	64
36.	There are fixed steps that scientists always follow to lead them without fail to scientific knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	65
37.	Sooner or later, the validity (i.e. truth) of scientific claims is settled by referring to observations of phenomena.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	66
38.	Scientists agree about the principles of logical reasoning that connect evidence with conclusions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	67
39.	Science is much less creative than writing poetry or composing music.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	68
40.	Scientific theories need not explain additional observations that were <u>not</u> used in developing the theories in the first place.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	69
41.	Scientists may, because of their background, personal beliefs and values, look for different types of evidence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	70
42.	Scientists try to identify possible bias in the work of other scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	71
43.	In carrying out an investigation, <u>no</u> scientist must be made to feel that s/he should reach a particular result.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	72
44.	Scientific activity is a minor feature of the world today.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	73
45.	Because science is an activity carried out by many different people, science reflects values and viewpoints related to society (e.g. views on women, political beliefs).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	74

46.	Science does not only take place in universities and technikons, but also in business, industry, classrooms, the outdoors, etc.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	75
47.	<i>Scientific fields such as archaeology and zoology differ from one another in many ways.</i> Because of this difference, very few are equally scientific with respect to purpose and philosophy.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	76
48.	The bodies (e.g. the different government departments) which supply money for scientific research influence the direction of science (i.e. which research to undertake).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	77
49.	Scientific ethics (i.e. system of morals) is <u>not</u> concerned with the possible harm that could result from scientific experiments.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	78
50.	Scientists can seldom play an important advisory role in matters of public interest (e.g. nuclear power or conservation of the environment).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	79
51.	Even where their own interests are at stake, scientists can be expected to be unbiased in many public matters (e.g. building a new highway near their home).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	80
52.	<i>Biologists classify organisms into groups and subgroups.</i> This is done in a manner that is unrelated to the structure and behaviour of the organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	81
53.	Biological classification systems are theoretical frameworks created by biologists for describing the great diversity of organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	82
54.	<i>In living organisms, most complex molecules are made up of chains of smaller molecules.</i> In each species, there are characteristic sequences of small molecules that make up complex molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	83
55.	Human beings depend on food webs (i.e. interlinked food chains) to obtain the energy and materials necessary for life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	84
56.	Offspring (i.e. young) are identical to their parents.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	85
57.	In humans, instructions for development from egg to adult are passed from parents to offspring (i.e. young) in a few hundred genes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	86
58.	The "mixing" of genes in sexual reproduction results in only a tiny variety of gene combinations among the offspring (i.e. young) of two parents.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	87
59.	Sometimes some of the "information" in a cell's DNA is changed.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	88
60.	Many of the basic functions of organisms, such as extraction of energy from nutrients, are carried out at the level of the cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	89
61.	The genetic information encoded in DNA molecules plays <u>no</u> role in the assembly of protein molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	90
62.	The chemical processes in the cell are controlled from both inside and outside the cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	91
63.	In an ecosystem, species are usually independent of every other species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	92
64.	To understand any one part of an ecosystem, we do <u>not</u> need to know how that part of the ecosystem interacts with the other parts of the ecosystem.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	93



65.	Ecosystems tend to show cyclic fluctuations around a state of near equilibrium.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	94
66.	Ecosystems remain constant even when very different new species appear.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	95
67.	Almost all life on earth is basically maintained by transformations of energy from the sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	96
68.	Coal and oil were formed millions of years ago.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	97
69.	<i>Carbon dioxide was removed from the atmosphere over millions of years. By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at approximately the same rate at which carbon dioxide was removed from the atmosphere.</i>	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	98
70.	The earth's present-day life-forms have always existed in their present form.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	99
71.	<i>The fossil record stretches back over millions of years. Since the beginning of the fossil record, most old life-forms, such as species, have disappeared.</i>	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	100
72.	The result of natural selection is that over successive generations within any species, the proportion of individuals that have inherited advantage-giving characteristics will remain the same.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	101
73.	New combinations or mutations of parents' genes can result in new characteristics which can be inherited.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	102
74.	Natural selection does not necessarily result in increasingly greater advantages of an organism's characteristics.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	103
75.	Evolution is <u>not</u> a ladder with humans finally emerging at the top as the most advanced species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	104
76.	Scientific understanding is less important to technology than accumulated practical knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	105
77.	More and more, technology is developing new instruments and techniques to advance scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	106
78.	As technology becomes more sophisticated (i.e. advanced), technology's links to science remain unchanged.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	107
79.	New scientific investigations often need new technology.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	108
80.	In the short term, scientific research affects societies and cultures more directly than engineering.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	109
81.	An engineering design usually does <u>not</u> operate within constraints (e.g. physical laws, economics, politics) that must be identified and taken into account.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	110
82.	<i>Different people place different values on different constraints (e.g. physical laws, economics, politics) that act on engineering designs (e.g. a person may favour a safer but more expensive design). Because of this difference in people's values, every engineering design problem has very few alternative solutions.</i>	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	111

83.	Engineering designs rarely need to be tested.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	112
84.	In spite of mechanical and electronic devices, the ultimate control of technological systems lies with people who understand the control process and the context in which the control process operates.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	113
85.	Many side effects of new technological designs are <u>not</u> predictable (i.e. cannot be forecast) because of the great complexity of modern technological systems.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	114
86.	A technological system is usually <u>not</u> designed so that its most likely way of failing would do the least harm.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	115
87.	Social and economic forces within a country have little influence on what technologies will be developed within that country.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	116
88.	Technology has strongly influenced the nature of human society.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	117
89.	Factors such as potential economic value or potential military applications rarely restrict (i.e. limit) the free flow of technological or scientific knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	118
90.	The relevant technical facts alone usually do <u>not</u> settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the proposal.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	119
91.	Most decisions on technology-related issues have to be made using incomplete information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	120
92.	All things of the physical world are made up of different combinations of about 100 chemical elements.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	121
93.	Apart from the pure elements, all substances consist of atoms from different elements joined together.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	122
94.	At extremely low temperatures nuclei of atoms may join together (i.e. fuse).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	123
95.	There is <u>no</u> natural radiation in the general environment (i.e. the world around us).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	124
96.	In the universe, energy appears in many forms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	125
97.	Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by an equal amount.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	126
98.	When atoms or molecules interact, they will usually end up in more order than they began with.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	127
99.	Different energy levels of molecules are associated with different arrangements of atoms in molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	128
100.	Reactions between the outer electrons of atoms involve far greater energy changes than reactions in the nuclei of atoms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	129
101.	There is a point or object in space that can serve as a single, absolute reference for something that is actually moving.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	130

102.	The observed wavelength of a wave is independent of the relative motion of the source of the wave with respect to the observer.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	131
103.	Materials that allow one range of wavelengths of electromagnetic radiation (e.g. visible light, ultraviolet light, X-rays) to pass through them, allow all other ranges of wavelengths to pass through them.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	132
104.	Every object in the universe exerts gravitational forces on every other object.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	133
105.	How materials conduct electricity is unrelated to the number of electric charges in them that are free to move.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	134
106.	A changing electric field produces a magnetic field.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	135
107.	In most biological respects, humans are like other living organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	136
108.	In spite of variations in features such as size and skin colour, humans are a single species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	137
109.	Humans have about the same range of social behaviour as other species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	138
110.	Technology has helped us make up for our biological disadvantages in our day-to-day lives.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	139
111.	The death rate of infants varies little throughout various parts of the world.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	140
112.	The mental development of normal children is characterised by the appearance of abilities (e.g. speech sounds, connected speech) in no particular order.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	141
113.	For most people the ability to learn lasts throughout life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	142
114.	Technology has added greatly to the choices which people have in controlling when, and how many, children they have.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	143
115.	Aging in humans is caused by factors both internal to the human body (e.g. changes in the hormonal system) and external to the human body (e.g. exposure to harmful substances).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	144
116.	Organ systems of the human body have specialised functions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	145
117.	<i>Internal control (i.e. co-ordination) is required for managing complex organ systems in the human body.</i> Hormones play <u>no</u> part in this control.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	146
118.	Any new-born animal will only show certain patterns of behaviour once it has been taught such behaviour.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	147
119.	The training of a person's muscles to perform certain tasks is only slightly affected by practice.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	148
120.	Very little learning appears to occur by linking a new piece of information with an existing piece of information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	149

- |      |   |  |     |
|------|---|--|-----|
| 121. | The human body does <u>not</u> produce all chemical substances (e.g. amino acids) that the body needs to operate normally.  | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 150 |
| 122. | Good health depends on avoiding too much exposure to substances that interfere with the body's operation, e.g. tobacco and alcohol.   | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 151 |
| 123. | Viruses can interfere with the human body's normal operation.   | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 152 |
| 124. | The immune system is the human body's own <b>second</b> line of defense against disease-causing organisms.  | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 153 |
| 125. | <i>The societal and physical conditions in which people live now are very different from those to which the human body was adapted long ago.</i> This change in the general living environment is a factor in determining the health of the general population. | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 154 |
| 126. | In different cultures people have different ideas about what is good mental health.   | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 155 |
| 127. | All people are able to cope the same with stressful environments.   | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 156 |
| 128. | Biological abnormalities (such as a chemical imbalance in the brain) cause no psychological disturbance.  | <input type="checkbox"/> T <input type="checkbox"/> F <input type="checkbox"/> ? | 157 |

**You have reached the end of the questionnaire.**

**THANK YOU VERY MUCH FOR YOUR PARTICIPATION!**



**APPENDIX D4**

U N I V E R S I T Y   O F   C A P E   T O W N

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**S C I E N C E   Q U E S T I O N N A I R E**

*Form PT-d*

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Science Education Unit, School of Education, University of Cape Town,  
Rondebosch 7700

## ABOUT THIS QUESTIONNAIRE

We are interested in finding out what you know about the Sciences in general. We know, that some of you will not have taken any science subjects in Matric, but please do not worry! **We are simply interested in what you know *now*, regardless of your matric subjects.** Therefore do not be afraid to answer "I don't know"!

This questionnaire is divided into two sections. In Section A, you are asked a number of questions about yourself and about your matric. In Section B, you are asked to decide whether statements are true or false or whether you do not know the answer.

*Your answers will remain totally confidential and will not be associated with your identity at any stage.*

We begin, then, with Section A.

Form PT

d

1-5

## SECTION A

1. Is this your very first year of registration at any Technikon or University? (Please tick the appropriate box)

Yes

No

2. Where are you presently studying? (Please tick the appropriate box)

Cape Technikon

☐

1

University of Cape Town

☐

2

6

3. In which School (Cape Technikon students) or Faculty (UCT students) are you currently registered? (Please tick the appropriate box)

**School**

Electrical Engineering

☐

11

Business Management

☐

12

Other (please specify):

☐

13

**Faculty**

Arts

☐

21

Science

☐

22

Social Sciences &amp; Humanities

☐

23

Other (please specify):

☐

24

7-8

4. How old will you turn this year?

years

9-10

5. Are you Male or Female? (Please tick the appropriate box)

M

1

F

2

11

6. What is your home language? (Please tick the appropriate box)

Afrikaans

☐

01

English

☐

02

Ndebele

☐

03

Northern Sotho

☐

04

Southern Sotho

☐

05

Swazi

☐

06

Tsonga

☐

07

Tswana

☐

08

Venda

☐

09

Xhosa

☐

10

Zulu

☐

11

Other (please specify):

☐

12

12-13



7. In which year did you pass your Matric?

19

14-

8. Through which Education Authority did you complete your Matric? *(Please tick the appropriate box)*

Cape Education Department (CED)	<input type="checkbox"/>	01
Department of Education and Training (DET)	<input type="checkbox"/>	02
Department of Education and Culture - House of Delegates (DEC)	<input type="checkbox"/>	03
Department of Education and Culture - House of Representatives (DEC)	<input type="checkbox"/>	04
Joint Matriculation Board (JMB)	<input type="checkbox"/>	05
Natal Education Department (NED)	<input type="checkbox"/>	06
Orange Free State Education Department	<input type="checkbox"/>	07
Transkei Education Department	<input type="checkbox"/>	08
Transvaal Education Department (TED)	<input type="checkbox"/>	09
Other (please specify): _____	<input type="checkbox"/>	10

16-

9. Which Science subjects did you take up to Matric? At Higher (HG) or Standard (SG) Grade?  
What symbol did you receive for each of them? *(Please tick the appropriate box or boxes)*

Subject	Grade	Symbol
None	Not Applicable	Not Applicable
Agricultural Sciences	<div><div>HG</div><div>1</div></div> <div><div>SG</div><div>2</div></div>	
Biology	<div><div>HG</div><div>1</div></div> <div><div>SG</div><div>2</div></div>	
Geography	<div><div>HG</div><div>1</div></div> <div><div>SG</div><div>2</div></div>	
Physical Science	<div><div>HG</div><div>1</div></div> <div><div>SG</div><div>2</div></div>	
Physiology	<div><div>HG</div><div>1</div></div> <div><div>SG</div><div>2</div></div>	
Other (please specify): _____	<div><div>HG</div><div>1</div></div> <div><div>SG</div><div>2</div></div>	

So far, so good! This is the end of Section A. Now please turn the page to start Section B.

## SECTION B

The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T) or FALSE (F), or whether you really DON'T KNOW (?) the answer. *Please tick the appropriate box.*

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. **Please take this sentence to be TRUE!** The statement to which you must respond refers to this true sentence.

**Please work swiftly and carefully, and try to answer *all* the questions.**

- |     |  |                            |                            |                            |    |
|-----|--|----------------------------|----------------------------|----------------------------|----|
| 10. | Our sun is a star.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 39 |
| 11. | Apart from our own, the universe contains many billions of galaxies.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 40 |
| 12. | In the universe there are many other bodies similar to our sun.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 41 |
| 13. | It seems that the entire known universe exploded into existence from a single hot, dense mass.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 42 |
| 14. | Our solar system came into existence a few thousand years ago.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 43 |
| 15. | There are more than twenty major planets in our solar system.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 44 |
| 16. | Apart from the planets, no other objects move around our sun.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 45 |
| 17. | Our knowledge of the universe comes to us mostly through the use of instruments we have developed, e.g. telescopes.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 46 |
| 18. | We live in the only known system of planets.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 47 |
| 19. | About three-quarters of the earth's surface is covered by land.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 48 |
| 20. | Many of the planets and moons in our solar system appear able to support life as we know it.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 49 |
| 21. | The sun orbits (i.e. moves around) the earth.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 50 |
| 22. | The moon orbits (i.e. moves around) the earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 51 |
| 23. | Varying radiation from the earth's hot interior is the basic cause of changes in climate on earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 52 |
| 24. | The earth's climate has changed very little over thousands of years.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 53 |
| 25. | <i>The earth has many resources of great importance to human life. Some resources can be readily renewed, some can be renewed only at great cost, and some cannot be renewed at all.</i> | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 54 |

26.	Fresh water is an essential resource for industrial processes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	55
27.	Forces within the earth affect its surface.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	56
28.	Wind and water, in its various forms, change the earth's surface to produce distinctive landforms (e.g. mountains, valleys, etc.).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	57
29.	The earth's atmosphere has been unaltered by the presence of life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	58
30.	Human activities have hardly changed the earth's land surface, oceans, and atmosphere.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	59
31.	Science takes for granted that the things and events in the universe do <u>not</u> occur in consistent patterns.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	60
32.	Science assumes that the basic rules about how the universe operates are the same throughout the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	61
33.	Scientists accept the idea that we will one day know everything there is to know about the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	62
34.	In science, ideas are usually rejected outright, rather than modified (i.e. changed).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	63
35.	Scientists working in different scientific fields disagree about what makes a scientific investigation valid.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	64
36.	Science has a distinctive (i.e. special) character as a way of enquiry.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	65
37.	In science, the findings of any one investigator or group are rarely checked by other scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	66
38.	One of the chief activities of scientists is the process of putting forward and testing hypotheses (i.e. provisional explanations).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	67
39.	<i>Scientists try to make sense of phenomena by inventing explanations for them.</i> These explanations use currently accepted scientific principles.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	68
40.	Scientific evidence can be biased (i.e. distorted) in the way that data are selected, recorded, interpreted or reported.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	69
41.	Scientists may, because of their background, personal beliefs and values, emphasise different interpretations of evidence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	70
42.	Scientists are expected to safeguard against possible bias in their own work.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	71
43.	Accepting new ideas without challenge is a normal part of science in building valid (i.e. truthful) knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	72
44.	When a new or improved scientific theory is put forward which explains more phenomena than the previous theory, the new theory eventually takes the previous one's place.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	73
45.	Scientific work (i.e. research and teaching) goes on in all nations of the world.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	74

46.	The direction of scientific research (e.g. which questions are considered worth asking) is hardly affected by influences within science itself.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	75
47.	The spreading of scientific information is unimportant to the progress of science.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	76
48.	Scientific fields such as chemistry and biology do <u>not</u> have fixed boundaries or borders.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	77
49.	Because of strongly held traditions in science, most scientists behave professionally and ethically (i.e. in a moral and honest way).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	78
50.	Scientific ethics (i.e. system of morals) is concerned amongst other things with the possible harmful effects of applying the results of research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	79
51.	Scientists can almost always bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	80
52.	When scientists classify organisms, they consider anatomy (i.e. structure) to be more important than behaviour and appearance.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	81
53.	Biological classification systems do <u>not</u> tell us anything about relationships among living things.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	82
54.	Keeping a great variety of species on earth is unimportant to human beings.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	83
55.	Maintaining relatively large populations of a great variety of species has no influence on the chance of some individuals of some species surviving under changed conditions, e.g. climate.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	84
56.	Offspring (i.e. young) differ in some respects from one another.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	85
57.	Each gene is one - or more than one - particular segment of a molecule of DNA.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	86
58.	New "mixes" of genes as a result of sexual reproduction are the only source of variation in the characteristics of organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	87
59.	Only some life-forms on earth are made up of cells.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	88
60.	The function or work of the cell is rarely carried out by different types of protein molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	89
61.	<i>Most organisms have many different cells.</i> In such organisms, most cells perform only the basic functions common to all cells.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	90
62.	In an ecosystem there are few interactions either between life-forms or between life-forms and the environment.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	91
63.	The interdependence of organisms in an ecosystem often results in an almost stable system over very long periods of time.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	92
64.	Ecosystems remain constant even when the climate changes a great deal.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	93
65.	Living organisms do <u>not</u> share with other natural systems the same principles of the conservation of matter and energy.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	94

66.	The elements that make up the molecules of living things are <u>not</u> recycled.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	95
67.	Coal and oil were formed from inorganic material.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	96
68.	The amount of life any environment can support is limited by the environment's most basic resources.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	97
69.	<i>The fossil record stretches back over millions of years.</i> Since the beginning of the fossil record, only small numbers of new life-forms, such as species, have appeared.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	98
70.	Life on earth has existed for about three thousand million years.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	99
71.	Natural selection <u>cannot</u> act upon biochemistry, anatomical features and behaviour.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100
72.	Natural selection is unlikely to lead to organisms with characteristics that are well adapted to survival in particular environments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	101
73.	Evolution is a ladder in which the lower life-forms are all replaced with superior forms.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	102
74.	The modern concept of evolution provides a unifying principle for understanding the history of life on earth.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	103
75.	<i>Engineers use technology together with design strategies (i.e. ways of designing) to solve practical problems.</i> Knowledge of science is usually also used in this process of solving practical problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	104
76.	Technology just provides tools for science - it seldom provides motivation and direction for theory and research in science as well.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	105
77.	New technology seldom needs new scientific understanding.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	106
78.	Engineers cannot design solutions for all our problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	107
79.	<i>Decisions in engineering inevitably (i.e. without fail) involve scientific judgements.</i> These decisions also involve social and personal values.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	108
80.	<i>In engineering, a design takes into account all the constraints (e.g. physical laws, economics, politics).</i> An optimum (i.e. "best") design arrives at some reasonable compromise (i.e. balance) among the different constraints.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	109
81.	It is practical for engineers to design something (be it a machine or a chemical process) without considering where and how it will be used.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	110
82.	All engineering systems need control to keep them operating properly, i.e. comparing information about what is happening with what we want to happen, and then making appropriate adjustments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	111
83.	Every engineering design will only have intended benefits and no unintended side effects.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	112
84.	People's psychological reactions to risk (e.g. their fear of flying or driving) do <u>not</u> necessarily match the reality of the risks involved.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	113

85.	No matter what precautions are taken or how much money is spent, any technological system can fail.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	114
86.	Technology has had little influence on the course of history.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	115
87.	Technological and social change influence each other.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	116
88.	The total effect of decisions by large numbers of individuals can influence the large-scale use of technology as much as pressure on government decisions can.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	117
89.	Technology-related decisions are likely to be influenced as much by politics as by technical factors.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	118
90.	There are one or more different kinds of atoms for each of the chemical elements.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	119
91.	Depending on temperature and pressure, every substance can exist in a number of different states (i.e. solid, liquid, or gas).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	120
92.	The way atoms bond together is determined by the arrangement of the outermost electrons in each atom.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	121
93.	<i>Radioactive nuclei are unstable and eventually break up. One can predict when a particular unstable nucleus will break up.</i>	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	122
94.	Most of what happens in the universe - such as the collapsing of stars, biological growth, the operation of machines - involves one form of energy being changed into another form.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	123
95.	The total amount of useful energy in a system such as a switched-off electric hot-water tank always remains the same.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	124
96.	The total amount of disorder in the matter making up the universe is increasing.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	125
97.	Matter, but not energy, occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	126
98.	Nothing in the universe - from atoms to living things to stars - is at rest, but is always moving relative to something else.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	127
99.	Changes in motion are always due to the effects of unbalanced forces.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	128
100.	The interaction between waves and matter is <u>not</u> influenced by the wavelength of the wave.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	129
101.	Things appear to have different colours because they reflect or scatter visible light of some wavelengths more than others.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	130
102.	The electromagnetic forces acting between atoms are vastly stronger than the gravitational forces acting between them.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	131
103.	Magnetic and electric forces are unrelated to one another.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	132
104.	<u>No</u> forces operate only inside the nucleus of an atom.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	133

105.	There is little evidence that the human species evolved from other organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	134
106.	The complex languages, technologies, and arts of humans distinguish them (i.e. set them apart) from any other species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	135
107.	<i>Over time human practices have changed from hunting-and-gathering to farming.</i> This change was an unimportant event in the history of the human species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	136
108.	A human does <u>not</u> develop from the fusion (i.e. joining together) of an egg cell and a sperm cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	137
109.	The death rate of infants is independent of factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	138
110.	<i>Compared to other species, humans have an exceptionally long period of development.</i> This long period of human development is related to the important role of the brain in human evolution.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	139
111.	<i>Human developmental stages occur with somewhat different timing for different people.</i> This difference in timing is unrelated to differing physiological factors and to people's differing experiences in life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	140
112.	Aging is an <b>abnormal</b> process in all humans.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	141
113.	<i>There appears to be a maximum life span for each species.</i> This includes humans.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	142
114.	The immune system plays an important role in the self-protection of humans from disease.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	143
115.	Reproduction is essential for a species to continue to exist.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	144
116.	The behaviour of different people results from the interaction between what they have inherited biologically and differences in the people's experiences.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	145
117.	People's senses (e.g. sight, hearing, etc.) respond to all the stimuli that they receive.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	146
118.	People's existing ideas usually do <u>not</u> influence learning even if the ideas affect how people interpret new facts and ideas.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	147
119.	In order to operate normally, the human body does <u>not</u> need replacement of the materials from which the body is made.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	148
120.	The good health of individuals is independent of people's collective effort to take steps to keep their air, soil, and water safe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	149
121.	The human body's own first line of defense against disease-causing organisms is to keep these organisms from entering the body.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	150
122.	Abnormal genes do <u>not</u> affect how human body parts or systems function.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	151
123.	Good mental health is unrelated to the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	152

124. At different times in history people have different ideas about what is good mental health. ☐ T ☐ F ☐ ? 153
125. *The diagnosis and treatment of mental disturbances can be particularly difficult.* This is because most people usually understand everything that goes on in their minds. ☐ T ☐ F ☐ ? 154
126. Psychological distress (such as the death of a close family member) does not affect any person's chance of becoming physically ill. ☐ T ☐ F ☐ ? 155

You have reached the end of the questionnaire.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!





## **Appendix E**

### **SETTING OF PERFORMANCE STANDARD**



## INSTRUCTIONS FOR USING THE "PERFORMANCE-SETTING FORM"

Before assisting in setting the performance standard for the scientific literacy test-items listed overleaf, it is important that you are aware of our definition of scientific literacy, the rationale behind the need for scientific literacy in South Africa, and the test's required function. All three aspects may influence your decision w.r.t. the desired performance on the items of the individuals taking this test. Therefore kindly read the following section.

## The Context

Definition

Scientific literacy is a desired level of depth and breadth of scientific understanding appropriate to the interests and needs of the person being taught, set within the context of the developmental, educational, economic and political needs and interests of a country at a given point in time.

Rationale

In an intensifying science-based and technological world, it is now widely accepted that a minimal understanding of science has become a prerequisite for effective citizenship. Furthermore, there is growing recognition in the industrialised world that scientific literacy is a crucial component of long-term economic growth. South Africa is currently facing an uncertain future but there appears to be little doubt that the development of a scientifically literate citizenry is a *sine qua non* for South Africa's economic prosperity and social progress.

Required function of the scientific literacy test

The scientific literacy test is being developed specifically to identify *minimally* scientifically literate *high school-leavers*, i.e. pupils who have completed Std 10. What exactly "minimally" means is what I am requesting you to help determine!

## Performance-setting procedure

The scientific literacy test consists of three dimensions or sub-tests, each with a different test-item pool. You have been allocated some, but not all, items. Each test-item is identified by a unique five-digit number. The letter appended to this number identifies the correct answer to the test-items: "T" for true, "F" for false. The original instructions for the test read as follows:

"The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE or FALSE. Sometimes a sentence, in an italics typeface, is written before the actual statement. Please take this sentence to be true! The statement to which you must respond refers to this true sentence."

Please proceed as follows:

1. Read the first test-item on the *Performance-Setting Form*. (Experience has shown that it is very useful to briefly scan *all* items initially.)
2. Imagine 100 *minimally* scientifically literate high school-leavers.
3. Placing the item within the context of the definition of, and rationale for, scientific literacy, please indicate in the appropriate box *how many of this group of 100 minimally scientifically literate high school-leavers SHOULD be able to answer the test-item correctly*.  
**PLEASE NOTE:** You are asked to make a decision about what a hypothetical minimally competent group of high school-leavers *should* be able to do, rather than what real high school-leavers *are* able to do.
4. Please repeat this performance-setting task for each of the remaining test-items.

Thank you very much for your time and effort!

## PERFORMANCE-SETTING FORM - LIFE SCIENCES AND NATURE OF SCIENCE

Code	Test-item	Number out of 100 *
51011F	<i>Biologists classify organisms into groups and subgroups. This is done in a manner that is unrelated to the structure and behaviour of the organisms.</i>	<input type="text"/>
51051F	Keeping a great variety of species on earth is unimportant to human beings.	<input type="text"/>
51052F	In obtaining the energy and materials necessary for life, human beings are independent of food webs (i.e. interlinked food chains).	<input type="text"/>
52022T	Each gene is one - or more than one - particular segment of a molecule of DNA.	<input type="text"/>
52031T	The "mixing" of genes in sexual reproduction results in a great variety of gene combinations among the offspring (i.e. young) of two parents.	<input type="text"/>
53012T	Many of the basic functions of organisms, such as extraction of energy from nutrients, are carried out at the level of the cell.	<input type="text"/>
53031F	The genetic information encoded in DNA molecules plays no role in the assembly of protein molecules.	<input type="text"/>
53051T	The chemical processes in the cell are controlled from both inside and outside the cell.	<input type="text"/>
53061F	<i>Most organisms have many different cells.</i> In such organisms, most cells perform only the basic functions common to all cells.	<input type="text"/>
54011T	In an ecosystem, every species depends, directly or indirectly, on all other species in that system.	<input type="text"/>
54041T	The interdependence of organisms in an ecosystem often results in an almost stable system over very long periods of time.	<input type="text"/>
54052T	Ecosystems cannot avoid changing when the climate changes.	<input type="text"/>
54053T	Ecosystems cannot avoid changing when very different new species appear.	<input type="text"/>
55011F	Living organisms do <u>not</u> share with other natural systems the same principles of the conservation of matter and energy.	<input type="text"/>
55021F	Only a small proportion of life on earth is basically maintained by transformations of energy from the sun.	<input type="text"/>
55031T	The elements that make up the molecules of living things are continuously recycled.	<input type="text"/>
55041T	Coal and oil were formed millions of years ago.	<input type="text"/>
55043T	<i>Carbon dioxide was removed from the atmosphere over millions of years.</i> By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at a much faster rate than at which it was removed from the atmosphere.	<input type="text"/>

\* Number out of 100 *minimally* scientifically literate high school-leavers who SHOULD be able to answer the test-item correctly

## **Appendix F**

### **VALIDATION OF PERFORMANCE STANDARD (QUESTIONNAIRE)**



U N I V E R S I T Y   O F   C A P E   T O W N



## **S C I E N C E   Q U E S T I O N N A I R E**

*BSLT Form.a* - SciOlymp95

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Science Education Unit, School of Education, University of Cape Town,  
Rondebosch 7700



## **ABOUT THIS QUESTIONNAIRE**

**Congratulations on being one of the top-placed competitors in the 1995 Science Olympiad!**

**This questionnaire is divided into two sections. In Section A, you are asked a number of questions about your matric, your science classes and about your home. In Section B, you are asked to decide whether statements are true or false or whether you do not know the answer.**

**Please remember that when we ask you questions about your science classes, we mean your classes in Biology, Physical Science, Physiology, Geography, etc. (i.e. classes in the Natural Sciences) and NOT your classes in Maths or Computer Science!**

**We begin, then, with Section A.**

## SECTION A

1. How old will you turn this year?

years

4-5

2. Are you Male or Female? (Please tick the appropriate box)

☐ M

1

☐ F

2

6

3. In which Standard are you this year?

Std.

7-8

4. At which school are you enrolled? (Please state the full school name)

9-38

5. Under which Education Department did your school fall previously? (Please tick the appropriate box)

Cape Education Department (CED)

☐

1

Department of Education and Training (DET)

☐

2

Department of Education and Culture - House of Delegates (DEC)

☐

3

Department of Education and Culture - House of Representatives (DEC)

☐

4

Natal Education Department (NED)

☐

5

Orange Free State Education Department

☐

6

Transkei Education Department

☐

7

Transvaal Education Department (TED)

☐

8

Private School

☐

9

Other (please specify): \_\_\_\_\_

☐

10

39-40

6. At school, are you a member of a science club or science society? (Please tick the appropriate box)

☐ Yes

1

☐ No

2

41

7. How often have you entered a school science fair or expo?

times

42

8. How often have you participated in the Science Olympiad (including this year)?

times

43

9. In this year’s Science Olympiad competition, which section did you answer apart from the General Section?

Biology Section

1

Physical Science Section

2

44

45

10. Which Science subjects do you take up to Matric? At Higher (HG) or Standard (SG) Grade? What symbol (from A to G) did you receive for each of them at the end of last year?  
(Please tick the appropriate box or boxes)

Subject		Grade		Symbol	
Agricultural Science	<div><div></div>1</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	46-4
Biology	<div><div></div>2</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	49-5
Geography	<div><div></div>3</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	52-5
Physical Science	<div><div></div>4</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	55-5
Physiology	<div><div></div>5</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	58-6
Other (please specify):	<div><div></div>6</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	61-6
<hr/>					
Mathematics	<div><div></div>7</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	64-6
Computer Science	<div><div></div>8</div>	<div><div>HG</div>1</div>	<div><div>SG</div>2</div>	<div><div></div></div>	67-6

11. How frequently does(do) your teacher(s) emphasise the following activities?

(Please tick only one box per row)

	Almost never	Seldom	Often	Very often	
	1	2	3	4	
Increasing students’ interest in science	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	70
Teaching science facts and principles	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	71
Teaching students how to design experiments	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	72
Preparing students for further study in science	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	73
Developing students’ problem-solving and inquiry skills	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	74
Developing students’ skills in laboratory techniques	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	75
Increasing students’ awareness of importance of science in daily life	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	76
Developing students’ skills in observing something systematically	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	77
Teaching biographies (i.e. life histories) of scientists	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	78
Teaching about applications of science to environmental issues	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	<div><div></div></div>	79

12. How frequently do you do each of the following activities in your science lessons?

(Please tick only one box per row)

	<i>Almost never</i>	<i>Seldom</i>	<i>Often</i>	<i>Very often</i>	
	1	2	3	4	
Watch films or videos	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	80
Carry out an experiment or systematic observation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	81
Watch a demonstration by the teacher of an experiment	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	82
Write reports on experiments or systematic observations	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	83
Discuss current issues and events in class	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	84
Read materials that were not part of the text book	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	85
Discuss current magazine articles or books related to science	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	86
Discuss TV programmes about science	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	87
Carry out your own science projects	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	88
Write reports on readings that were not part of the text book	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	89
Discuss career opportunities in scientific or technological fields	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	90

13. On average, approximately how many students are there in your science class(es)?

(Note: NOT in your whole standard!)

students

91-92

Please continue on the next page...!

14. The following statements describe practices which could have taken place in your science class or science laboratory sessions. **How often** does each practice **ACTUALLY** take place in **one of your typical** science classes or laboratory sessions? Simply give your opinion on all statements - there are no "right" or "wrong" answers!

(Please tick only one box per row)

	Never	Rarely	Some- times	Often	Always	
	1	2	3	4	5	
There is an opportunity for me to follow my own science interests in the science laboratory sessions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	93
In my science class, the teacher talks with each student.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	94
In my science class there is a clear set of rules for students to follow.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	95
In my science class, students give their opinions during discussions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	96
In the science laboratory sessions, I am required to design my own experiments to solve a given problem.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	97
My science teacher takes a personal interest in each student.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	98
Rules in my science class seem to change a lot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	99
My science teacher lectures without students asking or answering questions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100
In the science laboratory sessions, other students collect different data than I do for the same problem.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	101
My science teacher is unfriendly towards students.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	102
My science teacher explains what will happen if a student brakes a class rule.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	103
In my science class, students' ideas and suggestions are used during classroom discussions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	104
In the science laboratory sessions, I am allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	105
My science teacher helps each student who is having trouble with the work.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	106
My science teacher explains what the class rules are.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	107
In my science class, students ask the teacher questions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	108
In the laboratory sessions, I do different experiments than some of the other students.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	109
My science teacher considers the students' feelings.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	110
In the science laboratory sessions, the teacher decides on the best way for me to carry out the experiments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	111
Classroom discussions take place in my science class.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	112
In the laboratory sessions, I decide on the best way to proceed during experiments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	113

15. In a typical week, how many hours do you spend doing homework for

all school subjects	<div></div>	hours	114-5
science subjects only	<div></div>	hours	116-7

16. Please indicate how you feel about each of the following statements: *(please tick only one box per row)*

	<b>Strongly Agree</b>	<b>Agree</b>	<b>Not Sure</b>	<b>Dis-agree</b>	<b>Strongly Disagree</b>	
	5	4	3	2	1	
I enjoy science	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	118
I am good at science	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	119
I usually understand what we do in science at school	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	120
Science is useful in everyday problems	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	121
Science is more useful for boys than for girls	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	122
Science helps a person to think logically	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	123
It is important to know science to get a good job	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	124
I will use science in many ways as an adult	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	125

17. How often do you do each of the following: *(please tick only one box per row)*

	<b>Never</b>	<b>Rarely</b>	<b>Some-times</b>	<b>Often</b>	<b>Always</b>	
	1	2	3	4	5	
Try hard to do your best at school	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	126
Try harder if you obtain bad marks	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	127
Day-dream at school	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	128
Wait to the last minute before studying	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	129
Would rather do things other than studying	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	130

18. Most of my friends *(tick all boxes that apply)*

like science at school	<div></div>	1	131
do well in science at school	<div></div>	2	132
are really good students at school	<div></div>	3	133
hope to become scientists, doctors, or engineers	<div></div>	4	134
hope to go to a university, technikon or college	<div></div>	5	135
watch a lot of TV	<div></div>	6	136

19. In a typical week, how many hours do you spend watching TV?

<div></div>	hours	137-8
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20. In a typical month, how many times do you do each of the following activities?

read a science magazine	<input type="text"/>	times
read science-related articles in newspapers	<input type="text"/>	times
read science-related articles in women's magazines	<input type="text"/>	times
read a science book (cover to cover)	<input type="text"/>	times
watch a science-related programme on TV	<input type="text"/>	times
listen to a science-related programme on radio	<input type="text"/>	times

139  
140-  
142  
144  
145-  
147

21. What is your home language? *(Please tick the appropriate box)*

Afrikaans	<input type="checkbox"/>	01	Tsonga	<input type="checkbox"/>	08
English	<input type="checkbox"/>	02	Tswana	<input type="checkbox"/>	09
English & Afrikaans	<input type="checkbox"/>	03	Venda	<input type="checkbox"/>	10
Ndebele	<input type="checkbox"/>	04	Xhosa	<input type="checkbox"/>	11
Northern Sotho	<input type="checkbox"/>	05	Zulu	<input type="checkbox"/>	12
Southern Sotho	<input type="checkbox"/>	06	Other (please specify):	<input type="checkbox"/>	13
Swazi	<input type="checkbox"/>	07			

148-

22. How many brothers and sisters do you have?

150-

23. What is the highest level of education that your mother and father have completed? *(Please tick only one box per parent)*

	Mother	Father
less than Std 5	<input type="checkbox"/> 01	<input type="checkbox"/> 01
Primary school (Std 5)	<input type="checkbox"/> 02	<input type="checkbox"/> 02
High school (Std 10)	<input type="checkbox"/> 03	<input type="checkbox"/> 03
Technikon:		
National Diploma	<input type="checkbox"/> 04	<input type="checkbox"/> 04
Higher Diploma	<input type="checkbox"/> 05	<input type="checkbox"/> 05
Other advanced diploma	<input type="checkbox"/> 06	<input type="checkbox"/> 06
University:		
Bachelor's degree	<input type="checkbox"/> 07	<input type="checkbox"/> 07
Honours degree	<input type="checkbox"/> 08	<input type="checkbox"/> 08
Master's degree	<input type="checkbox"/> 09	<input type="checkbox"/> 09
PhD or other advanced degree	<input type="checkbox"/> 10	<input type="checkbox"/> 10
Professional degree (e.g. LLB, MBChB, etc.)	<input type="checkbox"/> 11	<input type="checkbox"/> 11

152-

24. Does your mother or father have an occupation that is directly related to (please tick only one box per parent)

	<i>Mother</i>	<i>Father</i>
Science	<input type="checkbox"/> 1	<input type="checkbox"/> 1
Engineering	<input type="checkbox"/> 2	<input type="checkbox"/> 2
Medicine	<input type="checkbox"/> 3	<input type="checkbox"/> 3
Technology	<input type="checkbox"/> 4	<input type="checkbox"/> 4
None of the above	<input type="checkbox"/> 5	<input type="checkbox"/> 5

156-7

25. Did you ever have a job during school holidays that was directly related to (please tick only one box)

Science	<input type="checkbox"/> 1
Engineering	<input type="checkbox"/> 2
Medicine	<input type="checkbox"/> 3
Technology	<input type="checkbox"/> 4
None of the above	<input type="checkbox"/> 5

158

26. Which of the following do you have in your home? (Please tick all boxes that apply)

a specific place to do your homework or to study	<input type="checkbox"/> 1	159
a bedroom of your own	<input type="checkbox"/> 2	160
a daily newspaper	<input type="checkbox"/> 3	161
a weekly news magazine (e.g. Newsweek, Time)	<input type="checkbox"/> 4	162
a science magazine (e.g. National Geographic, New Scientist)	<input type="checkbox"/> 5	163
an atlas or a globe	<input type="checkbox"/> 6	164
a PC (personal computer)	<input type="checkbox"/> 7	165
a pocket calculator	<input type="checkbox"/> 8	166

27. How many books do you estimate there are in your home? (Please tick the appropriate box)

fewer than 50	<input type="checkbox"/> 1
50-100	<input type="checkbox"/> 2
101-250	<input type="checkbox"/> 3
251-500	<input type="checkbox"/> 4
more than 500	<input type="checkbox"/> 5

167

28. Do you live (please tick all boxes that apply)

with your parents (with both your mother <u>and</u> your father)	<input type="checkbox"/> 1	168
with your mother only	<input type="checkbox"/> 2	169
with your father only	<input type="checkbox"/> 3	170
with a relative	<input type="checkbox"/> 4	171
in boarding school	<input type="checkbox"/> 5	172



29. My parents *(please tick all boxes that apply)*

- insist I do my school homework
- expect me to do well in science at school
- think that science is a very important subject
- would like me to have a career in science, medicine or engineering
- always encourage me to go to a university, technikon or college
- know a lot about science
- really enjoy doing things with me

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3
<input type="checkbox"/>	4
<input type="checkbox"/>	5
<input type="checkbox"/>	6
<input type="checkbox"/>	7

173

174

175

176

177

178

179

30. In the last two years, how many times have you and your parents visited each of the following places together?

- A museum
- A planetarium
- A zoo
- A botanical garden
- An art museum
- An art gallery

<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>

times

times

times

times

times

times

180

181

182

183

184

185

31. Which religion do you take on? *(Please tick the appropriate box)*

- Christianity
- Hinduism
- Islam
- Judaism
- Other
- None

<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>

1

2

3

4

5

6

186

32. Would you say you are religious? *(Please tick the appropriate box)*

- not at all
- moderately
- very

<input type="checkbox"/>
<input type="checkbox"/>
<input type="checkbox"/>

1

2

3

187

So far, so good! This is the end of Section A. Now please go to the next page to start Section B.

## SECTION B

The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T) or FALSE (F), or whether you really DON'T KNOW (?) the answer. *Please tick the appropriate box.*

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. **Please take this sentence to be TRUE!** The statement to which you must respond refers to this true sentence.

**Please work swiftly and carefully, and try to answer *all* the questions.**

- |     |   |                            |                            |                            |     |
|-----|---|----------------------------|----------------------------|----------------------------|-----|
| 33. | The earth is as old as the universe.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 188 |
| 34. | Our galaxy only contains a few thousand stars.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 189 |
| 35. | Light from the nearest star to our sun takes only a few minutes to reach us.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 190 |
| 36. | In the universe there are many other bodies similar to our sun.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 191 |
| 37. | Most of our knowledge of the universe comes from looking at very small slices of space and small intervals of time.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 192 |
| 38. | Compared to the earth's diameter, a very thick blanket of air surrounds the entire earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 193 |
| 39. | Many of the planets and moons in our solar system appear able to support life as we know it.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 194 |
| 40. | There is no liquid water at the surface of planets other than the earth.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 195 |
| 41. | <i>The earth's axis is tilted, i.e. slanted.</i> This tilt produces seasonal changes in the earth's climate.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 196 |
| 42. | Varying radiation from the earth's hot interior is the basic cause of changes in climate on earth.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 197 |
| 43. | The earth's climate has changed very little over thousands of years.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 198 |
| 44. | The oceans and atmosphere can only be changed by a limited amount before affecting human activities unfavourably.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 199 |
| 45. | <i>Elements such as carbon, oxygen, nitrogen, and sulphur, move slowly through the land, oceans, and atmosphere.</i> While doing so, elements change their chemical combinations. | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 200 |
| 46. | The earth's atmosphere has been unaltered by the presence of life.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 201 |
| 47. | Human activities have hardly changed the earth's land surface, oceans, and atmosphere.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 202 |
| 48. | Scientists share certain beliefs and attitudes about what they do and how they view their work.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 203 |

49.	Science takes for granted that the things and events in the universe do <u>not</u> occur in consistent patterns.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	204
50.	Science assumes that the basic rules about how the universe operates are the same throughout the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	205
51.	There are many aspects of our lives that cannot be usefully examined in a scientific way.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	206
52.	There are fixed steps that scientists always follow to lead them without fail to scientific knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	207
53.	Sooner or later, the validity (i.e. truth) of scientific claims is settled by referring to observations of phenomena.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	208
54.	Scientists disagree about the principles of logical reasoning that connect evidence with conclusions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	209
55.	The process of putting forward and testing hypotheses (i.e. provisional explanations) is <u>not</u> one of the chief activities of scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	210
56.	<i>Scientists try to make sense of phenomena by inventing explanations for them.</i> These explanations rarely use currently accepted scientific principles.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	211
57.	Scientific theories should explain additional observations that were <u>not</u> used in developing the theories in the first place.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	212
58.	Scientific evidence can be biased (i.e. distorted) in the way that data are interpreted, recorded, reported or selected.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	213
59.	Scientists may, because of their background, personal beliefs and values, emphasise different interpretations of evidence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	214
60.	Scientists try to identify possible bias in the work of other scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	215
61.	In carrying out an investigation, no scientist must be made to feel that s/he should reach a particular result.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	216
62.	Even though science is an activity carried out by many different people, science hardly ever reflects values and viewpoints related to society (e.g. views on women, political beliefs).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	217
63.	The spreading of scientific information is unimportant to the progress of science.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	218
64.	Scientific fields such as chemistry and biology have fixed boundaries or borders.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	219
65.	The bodies (e.g. the different government departments) which supply money for research influence the direction of science (i.e. which research to undertake).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	220
66.	Because of strongly held traditions in science, most scientists behave professionally and ethically (i.e. in a moral and honest way).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	221
67.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harm that could result from scientific experiments.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	222
68.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harmful effects of applying the results of research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	223

69.	Scientists can seldom bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	224
70.	<i>Biologists classify organisms into groups and subgroups.</i> This is done in a manner that is unrelated to the structure and behaviour of the organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	225
71.	Keeping a great variety of species on earth is unimportant to human beings.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	226
72.	In obtaining the energy and materials necessary for life, human beings are independent of food webs (i.e. interlinked food chains).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	227
73.	Each gene is one - or more than one - particular segment of a molecule of <b>DNA</b> .	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	228
74.	The "mixing" of genes in sexual reproduction results in a great variety of gene combinations among the offspring (i.e. young) of two parents.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	229
75.	Many of the basic functions of organisms, such as extraction of energy from nutrients, are carried out at the level of the cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	230
76.	The genetic information encoded in DNA molecules plays no role in the assembly of protein molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	231
77.	The chemical processes in the cell are controlled from both inside and outside the cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	232
78.	<i>Most organisms have many different cells.</i> In such organisms, most cells perform only the basic functions common to all cells.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	233
79.	In an ecosystem, every species depends, directly or indirectly, on all other species in that system.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	234
80.	The interdependence of organisms in an ecosystem often results in an almost stable system over very long periods of time.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	235
81.	Ecosystems cannot avoid changing when the climate changes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	236
82.	Ecosystems cannot avoid changing when very different new species appear.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	237
83.	Living organisms do <u>not</u> share with other natural systems the same principles of the conservation of matter and energy.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	238
84.	Only a small proportion of life on earth is basically maintained by transformations of energy from the sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	239
85.	The elements that make up the molecules of living things are continuously recycled.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	240
86.	Coal and oil were formed millions of years ago.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	241
87.	<i>Carbon dioxide was removed from the atmosphere over millions of years.</i> By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at a much faster rate than at which it was removed from the atmosphere.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	242
88.	The earth's present-day life-forms have evolved from common ancestors over many millions of years.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	243

89.	Life on earth has existed for only a few thousand years.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	244
90.	New combinations or mutations of parents' genes do <u>not</u> result in new characteristics which can be inherited.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	245
91.	Natural selection is likely to lead to organisms with characteristics that are well adapted to survival in particular environments.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	246
92.	Evolution is <u>not</u> a ladder in which the lower life-forms are all replaced with superior forms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	247
93.	The modern concept of evolution provides a unifying principle for understanding the history of life on earth.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	248
94.	New instruments and techniques being developed through technology make little contribution to scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	249
95.	Technology just provides tools for science - it seldom provides motivation and direction for theory and research in science as well.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	250
96.	Engineers can design solutions for all our problems.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	251
97.	In the short term, engineering affects societies and cultures more directly than scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	252
98.	<i>Engineering decisions without fail involve scientific judgements.</i> These decisions also involve social and personal values.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	253
99.	<i>In engineering, a design takes into account all the constraints (e.g. physical laws, economics, politics).</i> An optimum (i.e. "best") design arrives at some reasonable compromise (i.e. balance) among the different constraints.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	254
100.	Engineering designs almost always need to be tested.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	255
101.	<i>The effects of large numbers of relatively simple objects (e.g. refrigerators or solar cookers) may be individually small.</i> However, these effects may be collectively significant.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	256
102.	In spite of the great complexity of modern technological systems, all side effects of new technological designs are predictable (i.e. can be forecast).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	257
103.	People's psychological reactions to risk (e.g. their fear of flying or driving) match the reality of the risks involved.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	258
104.	No matter what precautions are taken or how much money is spent, any technological system can fail.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	259
105.	Social and economic forces within a country have little influence on what technologies will be developed within that country.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	260
106.	Technology has had little influence on the nature of human society.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	261
107.	The relevant technical facts alone usually do <u>not</u> settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the decision.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	262

108.	The total effect of decisions by large numbers of individual people can influence the large-scale use of technology as much as the pressure on decisions by government can.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	263
109.	Most decisions on technology-related issues have to be made using incomplete information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	264
110.	All things of the physical world are made up of different combinations of about 100 chemical elements.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	265
111.	Depending on temperature and pressure, every substance can exist in a number of different states (i.e. a solid, liquid, or gas).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	266
112.	The way atoms bond together is determined by the arrangement of the outermost electrons in each atom.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	267
113.	A low level of background radiation exists naturally in the general environment (i.e. the world around us).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	268
114.	In the universe, energy appears only in one particular form.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	269
115.	Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by an equal amount.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	270
116.	Arrangements of atoms in molecules are unrelated to different energy levels of the molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	271
117.	Energy as well as matter occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	272
118.	Nothing in the universe - from atoms to living things to stars - is at rest, but is always moving relative to something else.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	273
119.	Changes in motion are always due to the effects of unbalanced forces.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	274
120.	Things appear to have different colours because they reflect or scatter visible light of some wavelengths more than others.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	275
121.	Every object in the universe exerts gravitational forces on every other object.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	276
122.	The <i>electromagnetic</i> forces acting between atoms are vastly stronger than the <i>gravitational</i> forces acting between them.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	277
123.	Magnetic and electric forces are unrelated to one another.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	278
124.	In most <i>biological</i> respects, humans are unlike other living organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	279
125.	In spite of variations in features such as size and skin colour, humans are a single species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	280
126.	Technology has been of little use to us in overcoming our biological disadvantages in our day-to-day lives.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	281
127.	The death rate of infants is independent of factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	282

128.	Technology has added greatly to the choices which people have in controlling when, and how many, children they have.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	283
129.	Organ systems of the human body have unspecialised functions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	284
130.	The immune system plays an important role in the self-protection of humans from disease.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	285
131.	<i>Internal control (i.e. co-ordination) is required for managing and coordinating complex organ systems in the human body.</i> Hormones play an important part in this control.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	286
132.	Any new-born animal will show certain patterns of behaviour without having been taught such behaviour.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	287
133.	The behaviour of different people results from the interaction between what they have inherited biologically and differences in the peoples' experiences.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	288
134.	Much of learning appears to occur by linking a new piece of information with an existing piece of information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	289
135.	People's existing ideas usually do <u>not</u> influence learning even if the ideas affect how people interpret new facts and ideas.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	290
136.	In order to operate normally, the human body does <u>not</u> need replacement of the materials of which it is made.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	291
137.	The good health of individuals is independent of people's collective effort to take steps to keep their air, soil, and water safe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	292
138.	Abnormal genes do <u>not</u> affect how human body parts or systems function.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	293
139.	Good mental health is unrelated to the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	294
140.	Ideas about what is good mental health are the same in different time periods (i.e. at different times in history).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	295
141.	Biological abnormalities (such as a chemical imbalance in the brain) cause some kinds of severe psychological disturbance.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	296
142.	Psychological distress (such as the death of a close family member) does <u>not</u> affect any person's chance of becoming physically ill.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	297

**You have reached the end of the questionnaire.**

**THANK YOU VERY MUCH FOR YOUR PARTICIPATION!**

# **Appendix G**

## **SCIENTIFIC LITERACY SURVEY QUESTIONNAIRE**





UNIVERSITY OF CAPE TOWN

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# SCIENTIFIC LITERACY SURVEY

*BSLT Form.a*

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Science Education Unit, School of Education, University of Cape Town,  
Rondebosch 7700

## **ABOUT THIS QUESTIONNAIRE**

Congratulations on being selected in 1994 to study in your chosen field of learning! Although you might not be a science student, we are interested in finding out what you know about the Natural Sciences in general. We know, that some of you will not have taken any science subjects in Matric, but please do not worry! **We are simply interested in what you know *now*, regardless of your matric subjects.** Therefore do not be afraid to answer "I don't know"!

This questionnaire is divided into two sections. In Section A, you are asked a number of questions about your matric, your science classes and about your home. In Section B, you are asked to decide whether statements are true or false or whether you do not know the answer.

*Be assured that all your answers will remain totally confidential.*

Please remember that when we ask you questions about your science classes, we mean your classes in Biology, Physical Science, Physiology, Geography, etc. (i.e. classes in the Natural Sciences) and NOT your classes in Maths or Computer Science!

We begin, then, with Section A.

BSLT Form.a

1-5

**SECTION A**

1. In the last two months, have you completed this questionnaire before? (Please tick the appropriate box)

☐ Yes☐ No

2. Is this your very first year of registration at any University, Technikon, Teacher Training College or Nursing College? (Please tick the appropriate box)

☐ Yes☐ No

3. Where are you presently studying? (Please tick the appropriate box)

Cape Technikon

☐ 1

Peninsula Technikon

☐ 2

University of Cape Town

☐ 3

University of Stellenbosch

☐ 4

University of the Western Cape

☐ 5

Nursing College

☐ 6

Teacher Training College

☐ 7

4. In which School (Technikon students) or Faculty (University students) are you currently registered? (Please tick the appropriate box)

**CAPE TECHNIKON**

Business Informatics

☐ 11

Management

☐ 12

Life Sciences

☐ 13

Physical Sciences

☐ 14

Mechanical Engineering

☐ 15

Civil Engineering

☐ 16

Electrical Engineering

☐ 17

Other (please specify):

☐ 18**PENINSULA TECHNIKON**Art and Design and  
Journalism☐ 21Education and Secretarial  
Training, Languages and  
Communication☐ 22

Sciences

☐ 23Architecture Building and  
Civil Engineering☐ 24Electrical and Mechanical  
Engineering and Computer  
Data Processing☐ 25

Business Studies

☐ 26

continued for Universities on  
page 2

**UNIVERSITY OF CAPE TOWN**

Arts  31

Commerce  32

Engineering  33

Science  34

Social Science & Humanities  35

Other (please specify):  36

\_\_\_\_\_

**UNIVERSITY OF STELLENBOSCH**

Lettere en Wysbegeerte  41

Natuurwetenskappe  42

Opvoedkunde  43

Landbouwetenskappe  44

Handel en Administrasie  45

Ingenieurswese  46

Geneeskunde  47

Bosbou  48

Tandheelkunde  49

**UNIVERSITY OF THE WESTERN CAPE**

Science  51

Arts  52

Economics and Management Sciences  53

Education  54

Theology  55

Dentistry  56

Law  57

Community and Health Sciences  58

5. How old will you turn this year?

 years

6. Are you Male or Female? (Please tick the appropriate box)

☐ M. 1

☐ F. 2

7. In which year did you pass your Matric?

 19

8. At which school did you matriculate?

\_\_\_\_\_

**9. Through which Education Authority did you complete your Matric? (Please tick the appropriate box)**

Cape Education Department (CED)

☐ 01

Department of Education and Training (DET)

☐ 02

Department of Education and Culture - House of Delegates (DEC)

☐ 03

Department of Education and Culture - House of Representatives (DEC)

☐ 04

Joint Matriculation Board (JMB)

☐ 05

Natal Education Department (NED)

☐ 06

National Senior Certificate

☐ 07

Orange Free State Education Department

☐ 08

Transkei Education Department

☐ 09

Transvaal Education Department (TED)

☐ 10

Other (please specify): \_\_\_\_\_

☐ 11

15-16

**10. Which Science subjects did you take up to Matric? At Higher (HG) or Standard (SG) Grade? What symbol (from A to G) did you receive for each of them? (Please tick the appropriate box or boxes)****Subject**

None

☐ 1**Grade****Symbol**

17

Agricultural Sciences

☐ 2☐ HG 1☐ SG 2☐

18-20

Biology

☐ 3☐ HG 1☐ SG 2☐

21-23

Geography

☐ 4☐ HG 1☐ SG 2☐

24-26

Physical Science

☐ 5☐ HG 1☐ SG 2☐

27-29

Physiology

☐ 6☐ HG 1☐ SG 2☐

30-32

Other (please specify): \_\_\_\_\_

☐ 7☐ HG 1☐ SG 2☐

33-35

**Mathematics**☐ 8☐ HG 1☐ SG 2☐

36-38

**Computer Science**☐ 9☐ HG 1☐ SG 2☐

39-41

**11. What is your Matric aggregate symbol (i.e. overall result)?**

42

**12. At school, were you ever a member of a science club or science society? (Please tick the appropriate box)**☐ Yes 1☐ No 2

43



17. The following statements describe practices which could have taken place in your science class or science laboratory sessions. **How often** did each practice **ACTUALLY** take place in a **typical** science class or laboratory session in your last **two** years of school? Simply give your opinion on **all** statements - there are no "right" or "wrong" answers!

(Please tick only one box per row)

	Never	Rarely	Some- times	Often	Always	
	1	2	3	4	5	
There was an opportunity for me to follow my own science interests in the science laboratory sessions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	68
In my science class, the teacher talked with each student.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	69
In my science class there was a clear set of rules for students to follow.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	70
In my science class, students gave their opinions during discussions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	71
In the science laboratory sessions, I was required to design my own experiments to solve a given problem.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	72
My science teacher took a personal interest in each student.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	73
Rules in my science class seemed to change a lot.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	74
My science teacher lectured without students asking or answering questions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	75
In the science laboratory sessions, other students collected different data than I did for the same problem.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	76
My science teacher was unfriendly towards students.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	77
My science teacher explained what would happen if a student broke a class rule.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	78
In my science class, students' ideas and suggestions were used during classroom discussions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	79
In the science laboratory sessions, I was allowed to go beyond the regular laboratory exercise and do some experimenting of my own.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	80
My science teacher helped each student who was having trouble with the work.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	81
My science teacher explained what the class rules were.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	82
In my science class, students asked the teacher questions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	83
In the laboratory sessions, I did different experiments than some of the other students.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	84
My science teacher considered the students' feelings.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	85
In the science laboratory sessions, the teacher decided on the best way for me to carry out the experiments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	86
Classroom discussions took place in my science class.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	87
In the laboratory sessions, I decided on the best way to proceed during experiments.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	88



18. In a typical week in your last two years of school, how many hours did you spend doing homework for

all school subjects

hours

89-90

science\*subjects only

hours

91-92

19. Please indicate how you feel about each of the following statements: (please tick only one box per row)

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree	
	5	4	3	2	1	
I enjoy science	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	93
I am good at science	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	94
I usually understood what we did in science at school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	95
Science is useful in everyday problems	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	96
Science is more useful for boys than for girls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	97
Science helps a person to think logically	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	98
It is important to know science to get a good job	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	99
I will use science in many ways as an adult	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	100

20. How often did you do each of the following: (please tick only one box per row)

	Never	Rarely	Sometimes	Often	Always	
	1	2	3	4	5	
Tried hard to do your best at school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	101
Tried harder if you obtained bad marks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	102
Day-dreamed at school	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	103
Waited to the last minute before studying	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	104
Would rather have been doing things other than studying	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	105

21. Most of my friends (tick all boxes that apply)

liked science at school	<input type="checkbox"/>	1	106
did well in science at school	<input type="checkbox"/>	2	107
were really good students at school	<input type="checkbox"/>	3	108
hope to become scientists, doctors, or engineers	<input type="checkbox"/>	4	109
go to a university, technikon or college	<input type="checkbox"/>	5	110
watch a lot of TV	<input type="checkbox"/>	6	111

22. In a typical week, how many hours do you spend watching TV?

hours

112-

23. In a typical month, how many times do you do each of the following activities?

read a science magazine	<input type="text"/>	1	114
read science-related articles in newspapers	<input type="text"/>	2	115-6
read science-related articles in women's magazines	<input type="text"/>	3	117-8
read a science book	<input type="text"/>	4	119
watch a science-related programme on TV	<input type="text"/>	5	120-1
listen to a science-related programme on radio	<input type="text"/>	6	122

24. What is your home language? (Please tick the appropriate box)

Afrikaans	<input type="checkbox"/>	01	Tsonga	<input type="checkbox"/>	08
English	<input type="checkbox"/>	02	Tswana	<input type="checkbox"/>	09
English & Afrikaans	<input type="checkbox"/>	03	Venda	<input type="checkbox"/>	10
Ndebele	<input type="checkbox"/>	04	Xhosa	<input type="checkbox"/>	11
Northern Sotho	<input type="checkbox"/>	05	Zulu	<input type="checkbox"/>	12
Southern Sotho	<input type="checkbox"/>	06	Other (please specify):	<input type="checkbox"/>	13
Swazi	<input type="checkbox"/>	07			

123-4

25. How many brothers and sisters do you have?

125-6

26. What is the highest level of education that your mother and father have completed? (Please tick only one box per parent)

	Mother	Father
less than Std 5	<input type="checkbox"/> 01	<input type="checkbox"/> 01
Primary school (Std 5)	<input type="checkbox"/> 02	<input type="checkbox"/> 02
High school (Std 10)	<input type="checkbox"/> 03	<input type="checkbox"/> 03
Technikon:		
National Diploma	<input type="checkbox"/> 04	<input type="checkbox"/> 04
Higher Diploma	<input type="checkbox"/> 05	<input type="checkbox"/> 05
Other advanced diploma	<input type="checkbox"/> 06	<input type="checkbox"/> 06
University:		
Bachelor's degree	<input type="checkbox"/> 07	<input type="checkbox"/> 07
Honours degree	<input type="checkbox"/> 08	<input type="checkbox"/> 08
Master's degree	<input type="checkbox"/> 09	<input type="checkbox"/> 09
PhD or other advanced degree	<input type="checkbox"/> 10	<input type="checkbox"/> 10
Professional degree (e.g. LLB, MBChB, etc.)	<input type="checkbox"/> 11	<input type="checkbox"/> 11

127-  
130

27. Does your mother or father have an occupation that is directly related to (please tick only one box per parent)

	Mother	Father
Science	<input type="checkbox"/> 1	<input type="checkbox"/> 1
Engineering	<input type="checkbox"/> 2	<input type="checkbox"/> 2
Medicine	<input type="checkbox"/> 3	<input type="checkbox"/> 3
Technology	<input type="checkbox"/> 4	<input type="checkbox"/> 4
None of the above	<input type="checkbox"/> 5	<input type="checkbox"/> 5

131-2

28. Did you ever have a job (during school holidays or otherwise) that was directly related to (please tick only one box)

Science	<input type="checkbox"/> 1
Engineering	<input type="checkbox"/> 2
Medicine	<input type="checkbox"/> 3
Technology	<input type="checkbox"/> 4
None of the above	<input type="checkbox"/> 5

133

29. Which one of the following has had the MOST influence on what you are studying now? (Please tick only one box)

your mother	<input type="checkbox"/> 1
your father	<input type="checkbox"/> 2
a brother or sister	<input type="checkbox"/> 3
another relative	<input type="checkbox"/> 4
a teacher	<input type="checkbox"/> 5
a school counsellor	<input type="checkbox"/> 6
your friends	<input type="checkbox"/> 7
what you have read	<input type="checkbox"/> 8

134

30. Which of the following do you have in your home? (Please tick all boxes that apply)

a specific place to do your homework or to study	<input type="checkbox"/> 1
a bedroom of your own	<input type="checkbox"/> 2
a daily newspaper	<input type="checkbox"/> 3
a weekly news magazine (e.g. Newsweek, Time)	<input type="checkbox"/> 4
a science magazine (e.g. National Geographic, New Scientist)	<input type="checkbox"/> 5
an atlas or a globe	<input type="checkbox"/> 6
a PC (personal computer)	<input type="checkbox"/> 7
a pocket calculator	<input type="checkbox"/> 8

135

136

137

138

139

140

141

142

31. How many books do you estimate there are in your home? (Please tick the appropriate box)

fewer than 50  
50-100  
101-250  
251-500  
more than 500

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3
<input type="checkbox"/>	4
<input type="checkbox"/>	5

143

32. In your last two years of school, did you live (please tick all boxes that apply)

with your parents (with both your mother and your father)  
with your mother only  
with your father only  
with a relative  
in boarding school

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3
<input type="checkbox"/>	4
<input type="checkbox"/>	5

144

145

146

147

148

33. My parents (please tick all boxes that apply)

insisted I do my school homework  
expected me to do well in science at school  
think that science is a very important subject  
would like me to have a career in science, medicine or engineering  
always encouraged me to go to a university, technikon or college  
know a lot about science  
really enjoy doing things with me

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3
<input type="checkbox"/>	4
<input type="checkbox"/>	5
<input type="checkbox"/>	6
<input type="checkbox"/>	7

149

150

151

152

153

154

155

34. In the last two years, how many times have you and your parents visited each of the following places together?

A museum  
A planetarium  
A zoo  
A botanical garden  
An art museum  
An art gallery

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3
<input type="checkbox"/>	4
<input type="checkbox"/>	5
<input type="checkbox"/>	6

156

157

158

159

160

161

35. Which religion do you take on? (Please tick the appropriate box)

Christianity  
Hinduism  
Islam  
Judaism  
Other  
None

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3
<input type="checkbox"/>	4
<input type="checkbox"/>	5
<input type="checkbox"/>	6

162

36. Would you say you are religious? *(Please tick the appropriate box)*

not at all

moderately

very

<input type="checkbox"/>	1
<input type="checkbox"/>	2
<input type="checkbox"/>	3

163

37. We intend to follow-up this survey with a further survey in three or four years time. It would help us tremendously if you would be willing to state your present student number. However, you are under no obligation to do so. *Again, let us assure you that your answers will remain totally confidential!*

Student Number

<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
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164-  
175

**So far, so good! This is the end of Section A. Now please go to the next page to start Section B.**

## SECTION B

The questions are in the form of a statement. Please read each statement carefully and decide whether this statement is TRUE (T) or FALSE (F), or whether you really DON'T KNOW (?) the answer. *Please tick the appropriate box.*

Sometimes a sentence, in an *italics* typeface, is written before the actual statement. Please take this sentence to be TRUE! The statement to which you must respond refers to this true sentence.

Please work swiftly and carefully, and try to answer *all* the questions.

- |     |   |                            |                            |                            |     |
|-----|---|----------------------------|----------------------------|----------------------------|-----|
| 38. | The earth is as old as the universe.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 176 |
| 39. | Our galaxy only contains a few thousand stars.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 177 |
| 40. | Light from the nearest star to our sun takes only a few minutes to reach us.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 178 |
| 41. | In the universe there are many other bodies similar to our sun.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 179 |
| 42. | Most of our knowledge of the universe comes from looking at very small slices of space and small intervals of time.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 180 |
| 43. | Compared to the earth's diameter, a very thick blanket of air surrounds the entire earth.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 181 |
| 44. | Many of the planets and moons in our solar system appear able to support life as we know it.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 182 |
| 45. | There is no liquid water at the surface of planets other than the earth.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 183 |
| 46. | <i>The earth's axis is tilted, i.e. slanted.</i> This tilt produces seasonal changes in the earth's climate.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 184 |
| 47. | Varying radiation from the earth's hot interior is the basic cause of changes in climate on earth.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 185 |
| 48. | The earth's climate has changed very little over thousands of years.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 186 |
| 49. | The oceans and atmosphere can only be changed by a limited amount before affecting human activities unfavourably.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 187 |
| 50. | <i>Elements such as carbon, oxygen, nitrogen, and sulphur, move slowly through the land, oceans, and atmosphere.</i> While doing so, elements change their chemical combinations. | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 188 |
| 51. | The earth's atmosphere has been unaltered by the presence of life.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 189 |
| 52. | Human activities have hardly changed the earth's land surface, oceans, and atmosphere.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 190 |
| 53. | Scientists share certain beliefs and attitudes about what they do and how they view their work.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 191 |

54.	Science takes for granted that the things and events in the universe do <u>not</u> occur in consistent patterns.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	192
55.	Science assumes that the basic rules about how the universe operates are the same throughout the universe.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	193
56.	There are many aspects of our lives that cannot be usefully examined in a scientific way.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	194
57.	There are fixed steps that scientists always follow to lead them without fail to scientific knowledge.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	195
58.	Sooner or later, the validity (i.e. truth) of scientific claims is settled by referring to observations of phenomena.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	196
59.	Scientists disagree about the principles of logical reasoning that connect evidence with conclusions.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	197
60.	The process of putting forward and testing hypotheses (i.e. provisional explanations) is <u>not</u> one of the chief activities of scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	198
61.	<i>Scientists try to make sense of phenomena by inventing explanations for them.</i> These explanations rarely use currently accepted scientific principles.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	199
62.	Scientific theories should explain additional observations that were <u>not</u> used in developing the theories in the first place.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	200
63.	Scientific evidence can be biased (i.e. distorted) in the way that data are interpreted, recorded, reported or selected.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	201
64.	Scientists may, because of their background, personal beliefs and values, emphasise different interpretations of evidence.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	202
65.	Scientists try to identify possible bias in the work of other scientists.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	203
66.	In carrying out an investigation, no scientist must be made to feel that s/he should reach a particular result.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	204
67.	Even though science is an activity carried out by many different people, science hardly ever reflects values and viewpoints related to society (e.g. views on women, political beliefs).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	205
68.	The spreading of scientific information is unimportant to the progress of science.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	206
69.	Scientific fields such as chemistry and biology have fixed boundaries or borders.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	207
70.	The bodies (e.g. the different government departments) which supply money for research influence the direction of science (i.e. which research to undertake).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	208
71.	Because of strongly held traditions in science, most scientists behave <del>in</del> professionally and ethically (i.e. in a moral and honest way).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	209
72.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harm that could result from scientific experiments.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	210
73.	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harmful effects of applying the results of research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	211

74.	Scientists can seldom bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	212
75.	<i>Biologists classify organisms into groups and subgroups.</i> This is done in a manner that is unrelated to the structure and behaviour of the organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	213
76.	Keeping a great variety of species on earth is unimportant to human beings.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	214
77.	In obtaining the energy and materials necessary for life, human beings are independent of food webs (i.e. interlinked food chains).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	215
78.	Each gene is one - or more than one - particular segment of a molecule of DNA.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	216
79.	The "mixing" of genes in sexual reproduction results in a great variety of gene combinations among the offspring (i.e. young) of two parents.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	217
80.	Many of the basic functions of organisms, such as extraction of energy from nutrients, are carried out at the level of the cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	218
81.	The genetic information encoded in DNA molecules plays no role in the assembly of protein molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	219
82.	The chemical processes in the cell are controlled from both inside and outside the cell.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	220
83.	<i>Most organisms have many different cells.</i> In such organisms, most cells perform only the basic functions common to all cells.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	221
84.	In an ecosystem, every species depends, directly or indirectly, on all other species in that system.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	222
85.	The interdependence of organisms in an ecosystem often results in an almost stable system over very long periods of time.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	223
86.	Ecosystems cannot avoid changing when the climate changes.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	224
87.	Ecosystems cannot avoid changing when very different new species appear.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	225
88.	Living organisms do <u>not</u> share with other natural systems the same principles of the conservation of matter and energy.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	226
89.	Only a small proportion of life on earth is basically maintained by transformations of energy from the sun.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	227
90.	The elements that make up the molecules of living things are continuously recycled.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	228
91.	Coal and oil were formed millions of years ago.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	229
92.	<i>Carbon dioxide was removed from the atmosphere over millions of years.</i> By burning fuels such as coal and oil, carbon dioxide is passed back into the atmosphere at a much faster rate than at which it was removed from the atmosphere.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	230
93.	The earth's present-day life-forms have evolved from common ancestors over many millions of years.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	231



94.	Life on earth has existed for only a few thousand years.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	232
95.	New combinations or mutations of parents' genes do <u>not</u> result in new characteristics which can be inherited.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	233
96.	Natural selection is likely to lead to organisms with characteristics that are well adapted to survival in particular environments.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	234
97.	Evolution is <u>not</u> a ladder in which the lower life-forms are all replaced with superior forms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	235
98.	The modern concept of evolution provides a unifying principle for understanding the history of life on earth.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	236
99.	New instruments and techniques being developed through technology make little contribution to scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	237
100.	Technology just provides tools for science - it seldom provides motivation and direction for theory and research in science as well.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	238
101.	Engineers can design solutions for all our problems.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	239
102.	In the short term, engineering affects societies and cultures more directly than scientific research.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	240
103.	<i>Engineering decisions without fail involve scientific judgements.</i> These decisions also involve social and personal values.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	241
104.	<i>In engineering, a design takes into account all the constraints (e.g. physical laws, economics, politics).</i> An optimum (i.e. "best") design arrives at some reasonable compromise (i.e. balance) among the different constraints.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	242
105.	Engineering designs almost always need to be tested.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	243
106.	<i>The effects of large numbers of relatively simple objects (e.g. refrigerators or solar cookers) may be individually small.</i> However, these effects may be collectively significant.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	244
107.	In spite of the great complexity of modern technological systems, all side effects of new technological designs are predictable (i.e. can be forecast).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	245
108.	People's psychological reactions to risk (e.g. their fear of flying or driving) match the reality of the risks involved.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	246
109.	No matter what precautions are taken or how much money is spent, any technological system can fail.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	247
110.	Social and economic forces within a country have little influence on what technologies will be developed within that country.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	248
111.	Technology has had little influence on the nature of human society.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	249
112.	The relevant technical facts alone usually do <u>not</u> settle technology-related issues (such as whether a nuclear power station should be built near a city) in favour of the side for or against the decision.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	250

113.	The total effect of decisions by large numbers of individual people can influence the large-scale use of technology as much as the pressure on decisions by government can.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	251
114.	Most decisions on technology-related issues have to be made using incomplete information.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	252
115.	All things of the physical world are made up of different combinations of about 100 chemical elements.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	253
116.	Depending on temperature and pressure, every substance can exist in a number of different states (i.e. a solid, liquid, or gas).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	254
117.	The way atoms bond together is determined by the arrangement of the outermost electrons in each atom.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	255
118.	A low level of background radiation exists naturally in the general environment (i.e. the world around us).	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	256
119.	In the universe, energy appears only in one particular form.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	257
120.	Whenever the energy in one form (e.g. heat) or place decreases, the energy in another place or form increases by an equal amount.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	258
121.	Arrangements of atoms in molecules are unrelated to different energy levels of the molecules.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	259
122.	Energy as well as matter occurs in discrete units (i.e. separate "packets") at the level of molecules and atoms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	260
123.	Nothing in the universe - from atoms to living things to stars - is at rest, but is always moving relative to something else.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	261
124.	Changes in motion are always due to the effects of unbalanced forces.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	262
125.	Things appear to have different colours because they reflect or scatter visible light of some wavelengths more than others.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	263
126.	Every object in the universe exerts gravitational forces on every other object.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	264
127.	The <i>electromagnetic</i> forces acting between atoms are vastly stronger than the <i>gravitational</i> forces acting between them.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	265
128.	Magnetic and electric forces are unrelated to one another.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	266
129.	In most <i>biological</i> respects, humans are unlike other living organisms.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	267
130.	In spite of variations in features such as size and skin colour, humans are a single species.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	268
131.	Technology has been of little use to us in overcoming our biological disadvantages in our day-to-day lives.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	269
132.	The death rate of infants is independent of factors such as sanitation (i.e. drainage and sewage disposal), hygiene, and medical care.	<input type="checkbox"/> T	<input type="checkbox"/> F	<input type="checkbox"/> ?	270

- |      |  |                            |                            |                            |     |
|------|--|----------------------------|----------------------------|----------------------------|-----|
| 133. | Technology has added greatly to the choices which people have in controlling when, and how many, children they have.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 271 |
| 134. | Organ systems of the human body have unspecialised functions.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 272 |
| 135. | The immune system plays an important role in the self-protection of humans from disease.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 273 |
| 136. | <i>Internal control (i.e. co-ordination) is required for managing and coordinating complex organ systems in the human body.</i> Hormones play an important part in this control. | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 274 |
| 137. | Any new-born animal will show certain patterns of behaviour without having been taught such behaviour.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 275 |
| 138. | The behaviour of different people results from the interaction between what they have inherited biologically and differences in the peoples' experiences.                        | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 276 |
| 139. | Much of learning appears to occur by linking a new piece of information with an existing piece of information.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 277 |
| 140. | People's existing ideas usually do <u>not</u> influence learning even if the ideas affect how people interpret new facts and ideas.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 278 |
| 141. | In order to operate normally, the human body does <u>not</u> need replacement of the materials of which it is made.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 279 |
| 142. | The good health of individuals is independent of people's collective effort to take steps to keep their air, soil, and water safe.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 280 |
| 143. | Abnormal genes do <u>not</u> affect how human body parts or systems function.  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 281 |
| 144. | Good mental health is unrelated to the interaction of the psychological, biological, physiological, social and cultural aspects of a person's life.                              | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 282 |
| 145. | Ideas about what is good mental health are the same in different time periods (i.e. at different times in history).  | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 283 |
| 146. | Biological abnormalities (such as a chemical imbalance in the brain) cause some kinds of severe psychological disturbance.   | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 284 |
| 147. | Psychological distress (such as the death of a close family member) does <u>not</u> affect any person's chance of becoming physically ill.                                       | <input type="checkbox"/> T | <input type="checkbox"/> F | <input type="checkbox"/> ? | 285 |

You have reached the end of the questionnaire.

THANK YOU VERY MUCH FOR YOUR PARTICIPATION!

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